## THE PERISOMIC PLATES OF THE CRINOIDS.

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In nearly all Crinoids, recent and fossil, in which the free arms do not start out directly from the (first) radials, the lower arm joints are incorporated into the calyx either by soft tissues, or by means of plates to which the term *interradials* has been applied. The interradials are exceedingly variable in form and character, being in some groups well developed, rigid plates; while in others they are irregular, ill-formed pieces or mere limestone particles resting within soft tissues. The great difference in their structure among different groups led to the belief that the rigid and regularly arranged plates, which are so characteristic of the Camerata, did not belong to the same system of plates as the irregular, small pieces which unite the rays of recent Crinoids, and Dr. P. H. Carpenter applied to the former the term "calyx" interradials, as opposed to the interradial plates of the disk.

A somewhat similar distinction has been made respecting the plates which form the ventral pavement. The heavy, rigid plates of Palaeozoic forms were called "vault" plates, the small, irregular pieces of later and recent Crinoids "perisomic" or "disk" plates. The term "vault" was applied generally in cases in which mouth and food grooves are permanently closed, and "disk" where mouth and food grooves are opened out.

In the Camerata the interradials are arranged on a definite plan. They are stout, large, and united by close suture, so as to make the whole test to the bases of the free arms extremely rigid. In the Actinocrinidae the interradial series invariably commence with one plate which is followed by two in the second row, and two, three or four, according to species, in the succeeding ones. The posterior interradius is wider and split vertically into two halves by a series of anal plates which support the anal tube. In the other families of the Camerata, the Reteocrinidae excepted, the arrangement of the interradials is similar and equally regular. But in the Platycrinidae and Hexacrinidae the first row consists of three or more pieces, and in the Rhodocrinidae the first interradial is interposed between the radials. The plates forming the ventral side of the calyx are as rigid as those of the dorsal side, and none of them are described as pierced by water pores. They consist normally of five irregular

orals, of which the posterior one is larger and pushed in between the four others, and of the so-called interradial dome plates, which connect with the interradials of the dorsal cup. Occasionally there are outside the orals, a few other large pieces known as the radial dome plates. In some species the orals are unrepresented, and the whole ventral surface of the calyx is studded with interradial plates. The mouth in none of the Camerata is exposed, but the ambulacra with tightly closed food grooves are frequently visible.

The inner floor of the ventral covering in most of the Actinocrinidae is deeply grooved so as to form well-defined galleries which lead to the arm bases. Within these galleries is observed quite frequently, but, so far as we know, only in *Batocrinus, Eretmocrinus, Dorycrinus, Actinocrinus, Teleiocrinus* and *Physetocrinus*, a sort of second integument[1] parallel with the upper, which we took to be the disk. It consists of rather irregular, ill-formed plates, arranged like those at the upper surface. Each plate is connected with the corresponding upper one by small surfaces or pillars, but the plates among themselves are not in contact laterally leaving open spaces or meshes between them. They constitute, as it appears, a kind of internal lining or net-work, which extends from the first costals[2] and first interradials uninterruptedly to the margins of the orals, but no further. In some specimens the inner plates are less distinct, and we find at the inner floor small pillars or nodes, but nothing like plates. Within the galleries the intervening spaces are occupied by the ambulacra. The latter take the form of radiating tubes which run parallel with the inner floor, and branch as often as there are bifurcations in the calyx. Each tube is composed of four rows of plates, two above and two below, the upper ones alternately arranged with a furrow along the median line. The arrangement of the tubes and their mode of branching are best observed in natural casts. Looking at such a specimen, it seems indeed as if it could be scarcely possible that the surface as it there appears, with the vault plates removed, the ambulacra stretched out upon the upper face, resting within an integument of irregular pieces, could represent anything but the disk as exposed at the ventral surface of the Comatulae.

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[1] For a more complete description of this integument see Revision of the Palaeocrinoidea, Pt. III, p. 60.

[2] The terms costals, distichals and palmars are explained in a paper of Dr. Carpenter. (Ann. and Mag. Nat. Hist., July number, p. 15).

As another proof that there actually were two integuments in some Crinoids, we considered *Siphonocrinus armosus* from the Niagara group. This species, so well known from natural casts, apparently has a large trumpet-shaped, subtegminal anal tube, which crosses the mouth, overlies the upper part of the anterior ambulacral tubes, and is continued subtegminally all the way to the anterior side of the calyx, even beyond the arm regions, where it bends outward. The case is best illustrated if we imagine the disk of a recent Crinoid, with an anal tube like that of *Antedon regalis* (Chall. Rep. on Comat., Pl. 46, fig. 2), extended out all the way to the arm bases of the anterior ray, and covered by a vault.

It seemed to us beyond a doubt that in the foregoing cases two distinct structures covered the body, and it was upon these specimens, principally, that we based the opinion that the Camerata had a vault and a subtegminal disk. In taking this view, we did not overlook the fact that in many of these Crinoids, throughout different groups, the covering plates of the ambulacra are exposed upon the surface; but this seemed to us not to offer any serious objection, for the ambulacra in all Camerata, at one place or another, come to the surface from beneath the "vault," whether within the limits of the calyx or at the bases of the free arms. A very interesting case was illustrated by us in our Revision of the Palaeocrinoidea, Pt. III, Pl. V, fig. 9; in which the ambulacra do not enter the surface at the outer edges of the orals as in most species of *Platycrinus*, nor at the arm bases, but at a place midway between orals and arms, from beneath the smaller vault plates.

It is a striking fact, in the Crinoids as elsewhere, that some characteristics which are of the utmost importance from a morphological point of view, prove to be of comparative little value for classificatory purposes. This is the case to a very high degree with regard to the ambulacra of the Platycrinidae and Actinocrinidae, which may be tegminal or subtegminal. In the Platycrinidae the covering pieces are generally exposed in the calyx; in the Actinocrinidae, however, they are, as a rule, hidden from view, or were supposed to be so. But the opposite is also the case in both groups, and even within the limits of a genus. *Actinocrinus stellaris* from Belgium has large, well-defined covering pieces passing out from the outer edges of the orals; while most species of *Actinocrinus* only have in place of them so-called radial dome plates of a first, second and third order, according to the number of bifurcations in the calyx.

*Physetocrinus*, which is but a modified *Actinocrinus*, in some species has orals and radial dome plates, while in others the whole ventral surface is covered by numerous irregular pieces. *Actinocrinus multiradiatus*, on the contrary, has but few very large ventral plates which interlock with those between the rays. In most of the Actinocrinidae the interradials pass insensibly into the vault, there being no dividing line; while in *Batocrinus* generally, but not always, the interradials of the dorsal side are distinctly separated from those of the ventral side by the overarching brachials, a structure which led us at first to suppose the plates of the two sides to be morphologically distinct.

Similar differentiations we find in the ventral structure of the Platycrinidae and Hexacrinidae. In some of their species the pavement is made up entirely of massive plates, in others of comparatively thin pieces; while in still others the ventral surface is occupied almost exclusively by the orals. In both these groups absolutely no distinction can be made between interradials and vault plates. The first row, which generally consists of three plates, is peripheral, and is followed by other rows which are strictly ventral. The plates forming the second and upper rows, when such are present, interlock with each other and those of the first row, in a similar manner as the interradial plates of the dorsal cup in an *Actinocrinus*.

The conditions of the ventral pavement in the Melocrinidae, Rhodocrinidae and Glyptasteridae are very similar to those in the Actinocrinidae and Platycrinidae; many of them have uninterrupted rows of covering pieces exposed upon the surface, but the plates as a rule are smaller, less regular in their arrangement, and the orals and radial dome plates are more rarely represented. The lower interradials in all of them are definitely arranged, and there is no line of demarkation between the two hemispheres except that produced by the arms which pass out between them. In the Reteocrinidae, as in most of the Silurian Camerata, the whole ventral surface is covered by minute irregular pieces, and similar plates, with a few somewhat larger ones scattered among them, are interposed between the rays from the basals up. In the Crotalocrinidae and Acrocrinidae, the calyx ambulacra are exposed; their covering pieces are comparatively small, and remarkably regular in their arrangement.

Dr. P. H. Carpenter (Chall. Rep. on Stalk. Crin., pp. 165 and 166) agrees with us that the calcareous network beneath the vault of an *Actinocrinus* "corresponds to the limestone particles on the

surface of the internal casts, and represents the ambulacral plates developed in the perisome of recent Crinoids." He also admits "the complete resemblance between the ventral perisome of a recent Crinoid and the upper surface of the body beneath the vault of an *Actinocrinus*." Vault and ventral disk, he says, "are entirely distinct structures." Of the vault, he says further (p. 172) "I believe the oral or actinal system forming the vault of *Actinocrinus* to have been developed on the left larval antimer, in exactly the same way as the apical or abactinal system is developed on the right; but the oral system, instead of being limited to five oral plates as in Neocrinoids, reached a very extensive development, so that in its completest form it represents such a parallel to the apical or abactinal system as is to be met with in no other Crinoid." From these passages and others in the Challenger Report, especially on p. 180,[1] to which we shall refer again, it appears Dr. Carpenter supposed that in *Actinocrinus* all plates of the calyx up to the arm bases were abactinal, and all constituting the ventral side actinal, not only the orals and the so-called radial dome plates, but also the smaller plates, the so-called interradial dome plates, surrounding them. Similar views were held by us and advocated in Pt. II of the Revision (pp. 14 to 21), but abandoned in Pt. III, (pp. 16 to 27) as to the interradial dome plates, which we regarded as a continuation of the interradial plates of the dorsal cup, and not as actinal structures.

All interradial and interaxillaries, not only in the Camerata but wherever they exist in recent or fossil Crinoids, increase by multiplication in the growing animal, and as such, are auxiliary pieces filling up spaces between the rays and their sub-divisions. They increase primarily in an upward direction, but partly also by intercalation, secondary plates being introduced between the primary ones. It is owing to the intercalation of these supplementary pieces that the arrangement of the interradial plates in the upper rows is less regular than it might be otherwise. In the simpler forms such supplementary pieces are wanting, or they occur only around the arm bases; while in the Reteocrinidae they constitute the greater part of the interradial and interaxillary areas. In this family small pieces in large numbers continually formed in the growing Crinoid along the margins of the radials and brachials, and between

[1] All quotations from the writings of Dr. Carpenter, if not otherwise stated, are from the Challenger Report on the Stalked Crinoids.

the regular interradials, so as to isolate these from their fellows and from the plates of the rays.

The interradial plates, as stated before, are continued into the vault, and in species in which there are but one or two bifurcations in the calyx, this is quite readily perceived; but in the more complex forms the primary structure is frequently obscured by the introduction of numerous supplementary pieces, and it appears as if the plates of the ventral side belonged to a distinct system. Looking at a specimen of *Strotocrinus*, with its broad flanging rim, its hundred and more arms crowded around it, and its thousands of minute vault plates, decreasing in size outward, and in no way connected with the interradials of the dorsal side, it is not surprising that Carpenter regarded them, as we did at first, as structurally distinct from the latter.

To understand the structure of *Strotocrinus* let us refer to the allied genus *Steganocrinus*, in which in a similar way the arms branch off alternately like pinnules from the two main divisions of the rays; but while in *Strotocrinus* the lower part of the arms is incorporated into the calyx, forming a continuous rim, from which the free arms start off, in *Steganocrinus* the two divisions of the rays with their small alternate arms are free, and extend out laterally in the form of free tubular appendages. Now, it is very interesting to find that in *Steganocrinus* the interradials meet the plates of the dome in such a manner that it is absolutely impossible to draw a line between them (see *Steganocrinus pentagonus*, Iowa Geol. Rep. Hall., Vol. I, Pt. II, Pl. 10, figs. 6 a, b.). The case of *Steganocrinus* becomes the more instructive because this genus with its free arms may be regarded as representing an early stage in the developmental history of *Strotocrinus*.

A structure similar to that of *Steganocrinus* is found in all Camerata in which the arms become free after the first bifurcation, and from this condition all gradations can be traced to the complex structure of *Strotocrinus*. We are therefore of the opinion that the interradials interposed between the rays, and those at the dome, must be regarded as parts of the same element, and as representing a system of plates introduced between the actinal and abactinal systems, but actually belonging to neither.

More than in the Actinocrinidae, Dr. Carpenter differs from us as to the structure of the Platycrinidae. The ventral pavement of an *Actinocrinus* he calls "a structure sui generis," *i. e*, different from

that of a *Platycrinus*. He is inclined to believe (Chall. Rep. on Stalk. Crin., p. 180), "that the vault of a Platycrinoid corresponds collectively to the orals, interradials, ambulacral and anambulacral plates of Neocrinoids." He regards (p. 178) the peripheral portion of the "vault," by which he means the zone between the so-called summit plates and the radials, as generally corresponding to the large interradial of *Cyathocrinus*, and to the single interradial of *Coccocrinus*. As to the plate of *Cyathocrinus* we cannot agree with him for reasons which will be stated further on. That of *Coccocrinus* obviously represents the "calyx interradials" of *Platycrinus*, and not a plate of the peripheral zone.

In referring to *Marsupiocrinus* he says (p. 176), "I have a very strong impression that the so-called vault of this genus is really the strongly plated ventral perisome," and "I cannot see any such essential difference between it and the plated disk of *Pentacrinus wyville-thomsoni* or of many *Antedons* (Pl. XVII, fig. 6; Pl. LV.) as would lead to the supposition that the homologue of the latter is to be sought for beneath the vault of *Marsupiocrinus*." He then alludes to the closure of the mouth, and to the covering pieces proceeding from the perisome, which may have been immovably closed down over the food grooves: "They were thus converted into tunnels, but were still 'external,' in the sense of not being covered by a 'tegmen,' as those were which formed the tubular skeleton beneath the vault of the Actinocrinidae."

We have pointed out before that the covering pieces are exposed not only in the Platycrinidae, but quite frequently also in other families of the Camerata, exceptionally even in the genus *Actinocrinus*. Now, if it were true that in Crinoids in which the calyx ambulacra are entirely subtegminal, and not only the ambulacra but the whole disk is covered in by a structure "*sui generis*," and on the contrary, in forms in which the ambulacra are exposed there is no vault, and the plates in which the ambulacra rest form the disk, it seems to us that the two groups should be distinguished as separate orders; and it would seem to follow that all attempts heretofore made toward classifying the Crinoids would be altogether arbitrary and worthless. It was these considerations which led us to believe that the integuments in both cases must be the same thing, either a vault or a disk, the plates either all vault pieces or all perisomic. The evidence seemed to be conclusive that the disk, at least in some groups, was

subtegminal, and this, which was accepted by leading authorities, led us to assume that in all Camerata the true disk was covered in by a vault. In fact this seemed to be corroborated by the nature of the plates, which, although varying considerably in size and number, in all these Crinoids are arranged on the same general principle, forming in all of them a compact rigid test, and in all of them mouth and food grooves being perfectly closed.

We have already stated that in some species of *Platycrinus* the ambulacra make their appearance not at the margins of the summit plates, but at some point between the orals and the arm bases, from beneath the upper ring of interradials. In these species, applying Carpenter's interpretation, the lower interradials would be perisomic for they enclose the ambulacra, and the upper ones vault plates because they do not. In *Pterotocrinus*, the last survivor of the Hexacrinidae, the vault, as Dr. Carpenter admits (p. 177), "seems to have had a closer resemblance to that of *Actinocrinus* than is the case in most Platycrinidae, for it has radial dome plates of the first, second, and even occasionally of the third order." Such radial dome plates, he supposed, existed also in some Platycrinidae, and he asserts "There was a membranous disk, the radial regions of which were traversed by the ciliated food grooves beneath the ambulacral skeleton above; while the inter-palmar regions supported the interradial plates of the vault." In the Actinocrinidae, however, he thought, the tegmen was further extended so as to cover the whole ventral surface.

We never imagined that *Platycrinus* had anything but a membranous disk, but we thought that the disk was continued underneath the interradial plates all the way to the arm bases. Neither did we suppose there were any further plates above the food grooves but the alternating pieces; nor that the latter were true vault plates as Dr. Carpenter on p. 179 seems to have inferred we did. We held that, while in the typical *Actinocrinus* the interradial dome plates meet over the ambulacra, and form more or less elevated ridges upon the surface, the "vault" of the Platycrinidae, by opening out, exposed the covering pieces, and these were gradually incorporated into the test. In a typical Platycrinoid the covering pieces are so modified as to lose almost altogether their original character, being as large and nearly as heavy as the surrounding plates, and they are united with the latter, and with one another, by close suture. In some of the later Platycrinidae the covering pieces even may have

been separated from the food grooves, for in the internal casts nothing is found but the impressions of these plates, while in casts of *Actinocrinus*, from the same locality, and in casts of certain Silurian Platycrinidae, probably *Cordylocrinus* or *Culicocrinus*, in which the covering pieces perhaps were less modified, the outlines of the ambulacra are sometimes sharply delineated, and apparently formed solid tubes embracing the ambulacral vessels and food grooves.

It is to be observed, that while Dr. Carpenter regarded the interradial pieces of *Platycrinus* as perisomic plates, he alludes to the ventral covering of that genus as a vault, including the *anambulacral* plates (p. 180); while in speaking of the ventral surface of the Reteocrinidae, Ichthyocrinidae and the genus *Glyptocrinus*, he generally applies the terms "disk" and "interpalmar area." We allude to this fact, as he criticised us on p. 166 for using these terms indiscriminately in our writings. He explains the terms as follows: "The expression 'oral disk' or 'ventral disk' is universally used to denote the upper surface of the visceral mass of a Crinoid, *i. e.*, that in which the mouth is placed with the food grooves radiating outwards from the peristomial area around it." The ventral covering of *Platycrinus*, accordingly, should be called a disk like that of *Glyptocrinus*, if it really is as, he maintains, morphologically in a similar condition.

The ventral structure of the Melocrinidae and Rhodocrinidae, Carpenter probably supposed to have been in the same condition as that of the Actinocrinidae and Platycrinidae, a disk when the ambulacra are exposed, and a vault when they are concealed. He considers *Glyptocrinus* in connection with the Reteocrinidae and Ichthyocrinidae, in all of which the ventral pavement is composed of an immense number of very minute, irregularly arranged pieces, which in the Ichthyocrinidae are traversed by regular rows of alternating pieces passing out from the mouth to the arms; in the other families, however, such alternating plates, if present at all, are found only near the arm bases. Carpenter says in reference to these groups (p. 185), "I venture to think that in the case of *Glyptocrinus*, *Reteocrinus* and *Xenocrinus*, and also of the Ichthyocrinidae, the resemblance to the Pentacrinidae, Apiocrinidae, and Comatulidae is such as to leave no reasonable doubt that the so-called vault of these Palaeocrinoids is homologous with the ventral surface of the body in the Neocrinoids." This is perfectly true as to *Taxocrinus* and *Onycho-*

*crinus*, and probably the Ichthyocrinidae generally, in which mouth and food grooves are exposed, as we now know from actual observation[1]; but in the case of *Reteocrinus* and *Glyptocrinus* he had no proof beyond a superficial resemblance of the plates. Similar plates occur among species of the Actinocrinidae and Melocrinidae in the same genus, together with species with large plates, and all of these must be perisomic or none of them.

We now take up the Inadunata, which we have sub-divided in Pt. III of the Revision, into Larviformia and Fistulata.

The Inadunata Larviformia were regarded by us as representing the larval state of the Crinoids in a persistent form. The most complex Actinocrinoid or Cyathocrinoid must have passed in early life through a stage in which it closely resembled *Haplocrinus*, when the entire calyx consisted of basals—sometimes underbasals—radials, and orals. To these plates subsequently in *Symbathocrinus* an anal plate was added, but this disappeared in the later *Allagecrinus*. The three stages here alluded to, which are represented phylogenetically by distinct genera or families within the group, recur in the embryonic development of recent Crinoids.

The most characteristic embryonic feature of this group, is the covering of the ventral side by orals only. The plates of *Haplocrinus* were called by us orals in Pt. II of the Revision; but when later on we thought we had discovered centrally within this ring of plates another plate, we regarded this as the representative of the orals (Rev. Pt. III, pp. 31 to 34), and those surrounding it as interradial plates. Subsequently discovering conclusively that such a plate does not exist, we admitted our mistake[2] and recognized the *scheitelplatten* as orals. The Larviformia, therefore, have neither interradial nor interambulacral plates, and that they were in a low state of development is seen also by their arm structure. By far the most of them have but one arm to the ray, and their arm joints are immovably united by suture, but the union between radials and brachials is by articulation. Even in *Haplocrinus*, probably the lowest known form of this group, the radials are perforated. The earliest Larviformia known to us are from the Upper Silurian, but

[1] Discovery of the Ventral Surface of Taxocrinus and Haplocrinus, and consequent Modifications in the Classification of the Crinoidea, by Charles Wachsmuth and Frank Springer; Proc. Acad. Nat. Sci. Phila., 1888, pp. 337–363.

[2] Ibid., p. 340.

these were evidently preceded by lower forms, which have so far escaped notice, owing perhaps to their diminutive size. We think this the more probable as the species throughout this group are exceedingly small, some of them almost microscopic.

From *Haplocrinus* to *Hybocrinus* and *Heterocrinus* there is but a small step. All three have compound radials, and in the two latter the ventral sac, which represents the best character of the Fistulata, is in its first stage of development. The transitions from *Symbathocrinus* through the Hexacrinidae to the Actinocrinidae are equally gradual, in the latter the orals being carried inward by supplementary plates interposed between radials and orals. *Symbathocrinus* has an anal plate, and its orals had already that asymmetric arrangement—the posterior one larger and interlocking with the four others—which they retain throughout the Camerata. The introduction of a single interradial plate between the proximal brachials transforms *Allagecrinus* into either *Coccocrinus* or *Culicocrinus*.

We formerly arranged among the Larviformia also the Gasterocomidae, but these will have to be removed to the Fistulata or be placed in a new subgroup. We now think that the Larviformia should be restricted to forms in which the radials are directly followed by the orals.

The *Inadunata Fistulata*, like the Inadunata Larviformia, have no interradials in the dorsal cup, the anal piece excepted, but all have interambulacral plates. Four of the interradial spaces of the dome are raised but little above the level of the arm bases, but the posterior area is extended upwards, and formed into a sac or tube of various forms, frequently rising beyond the tips of the arms. This appendage, which in all probability embraced a large portion of the visceral cavity, must not be confounded with the anal tube of the Camerata, which simply contains the rectum. The ventral sac is generally the only part of the ventral pavement preserved in the specimens, and even this in most cases but fragmentarily. It is either tubular, balloon-shaped, spiral or club shaped, and is generally pierced by pores, which, however, do not penetrate the body of the plates but merely enter the edges. The structure of the four other sides is satisfactorily known only in the Cyathocrinidae and Anomalocrinidae, and fragmentarily in the Hybocrinidae, Poteriocrinidae and Encrinidae, enough to indicate that our former definition, giving to all Fistulata but one ring of interradials, was erroneous.

We have recently been fortunate in procuring from Montgomery Co., Indiana, a large number of specimens, some 50 or 60, comprising 7 species of *Cyathocrinus* in which the entire ventral structure is in excellent preservation, in many of them to the very end of the ventral sac. They were obtained by removing the arms in some of the most perfect specimens, a sacrifice for which we were richly rewarded. We have also procured from Sweden, through the kindness of Prof. G. Lindström, careful drawings of some of the types in the Stockholm Museum which, together with the specimens above mentioned, throw a flood of new light upon the ventral structure of this difficult group, and lead to the conclusion that the various species are built on a similar plan, and do not differ so essentially as it appeared to us at first from Angelin's figures. The most aberrant form is probably represented by *Cyathocrinus alutaceus*, of which we give an enlarged figure (Pl. IX, fig. 1). In this species, the greater part of the ventral surface is occupied by 5 large well defined orals which are arranged in the same manner as those of the Camerata; the posterior plate is larger, and its upper end is inserted between the four others. The orals are surrounded by numerous irregular pieces, of which the outer ones abut against the radials. There are no large interradial plates, nor regular rows of side or covering pieces such as we find in *Cyathocrinus laevis*, but alternating with the orals, and resting against them, there is toward each ray a sub-triangular piece, resembling the so-called radial dome plates of *Platycrinus*.

The specimens, Pl. IX, figs. 2–3, both of which Angelin referred to *Cyathocrinus laevis* are either distinct species, or one of them is in a more advanced stage of growth. That represented by fig. 3 (Iconogr. Crin. Suec., Pl. 26, fig. 2) probably at one time had orals like *C. alutaceus*, but these were partly resorbed and replaced by other plates. In fig. 2 (Iconogr. Crin. Suec., Pl. 26, fig. 3*b*), the resorption of the orals was apparently complete, and their place is occupied by irregular covering pieces, which join in the center. Farther out the ambulacra have well defined side pieces, and small covering plates close the food grooves.

A very different structure is seen in the specimen, Revision Palaeocr. Pt. III, Pl. IV, fig. 2, from the Burlington and Keokuk Transition beds; in which it appears as if there had been 5 large interradial plates, leaving a wide open space in the center. The plates meet laterally, and form upon their edges deep grooves for the

reception of the ambulacra. In another specimen of the same species, fig. 6, on the same plate, four of the "interradial plates" are almost completely covered by minute, very delicate perisomic pieces, but of the posterior one the greater part of the surface is bare. In *Cyathocrinus iowensis*, Pl. X, figs. 2–3, the larger plates are so closely united that it appears as if they formed a continuous undivided ring around the peristome, and served as a support for the delicate perisomic plates on top. This was the opinion of Wachsmuth, who in 1877 (Amer. Journ. Sc., Vol. XIV, pp. 183 and 184), regarded them as constituting a sort of consolidating apparatus like that described by Roemer in *Cupressocrinus*. We afterwards (Revision Pt. I, p. 12), suggested that the "consolidating plates" of *Cyathocrinus*, and those of *Cupressocrinus*, were structurally identical with the deltoids of the Blastoidea, and both homologous with the orals in the *Antedon* larva. Similar views were expressed by Prof. Zittel, Dr. Carpenter, and lately by Dr. Neumayr who all agreed that those plates in *Cyathocrinus* were orals. This interpretation, which at first seemed most plausible was abandoned by us in 1884, and also by Carpenter, owing to a morphological difficulty which it involved; for the ambulacra would then have to pass *over*, and not *between* the edges of the plates, a combination which seemed to us at variance with the nature of the orals. Since then, until lately, we have regarded these plates as interradials; but with considerable hesitation, for the plates are neither interradial nor interambulacral, but for the greater part *sub*-ambulacral. In their relations to surrounding parts they differ essentially from the interradials of *Platycrinus* or those of any other Camerate genus. Besides in *Platycrinus* the ambulacra rest against the edges of the interradials, and only the covering pieces are exposed on the surface; while in most of the Cyathocrinidae, if not in all, the whole ambulacrum rests on top of them, and the small perisomic plates sustain toward the side and covering pieces the same relations as the interradial plates of *Platycrinus*. That the plates are not orals, is further proved by the fact that there are in *Cyathocrinus iowensis* other large plates covering the peristome, which naturally represent them. The orals, which in *C. alutaceus* are unchanged through life, apparently were wholly or partly resorbed in other species, and their places occupied by large covering plates, of which the proximal ones joined in the center. This is well shown in the specimens Pl. IX, figs. 5, 7, 8, 9, and Pl. X, figs. 1–3, and seems to have been the case in *Cyathocrinus laevis* Pl. IX, figs. 2 and 3, and *Euspirocrinus spiralis*, Pl. IX, figs.

4–5; but while in all of the former species the ambulacra rest between small irregular perisomic plates which pass up from the upper ends of the radials, *Euspirocrinus* has four large "interradial" plates, and the corresponding space of the posterior side is taken up completely by the ventral tube. Whether these four plates were covered like those of *C. iowensis* and *C. gilesi* cannot be ascertained from the specimen, nor can we say whether the Silurian Cyathocrinidae generally had a large plate beneath their smaller ones; but we are convinced that such a plate is present in all Subcarboniferous species of *Cyathocrinus*.

Conceding now that those plates of *Cyathocrinus* are not orals, what are they? Interradial plates? It seems to us the fact that they support the ambulacra and are covered by perisome, proves as completely that they are not interradials as that they are not orals. If they were *calyx interradials*, the "vault" would be placed beneath the disk, while if they were *perisomic* plates there would be two disks on top of one another. Besides, the plates are subtegminal and decidedly subambulacral, and the question arises are they not wholly or in part subambulacral plates.

We have examined the two specimens of *Cyathocrinus iowensis* figured by Meek and Worthen (Geol. Rep. Illinois, Vol. V, Pl. 9, figs. 13 and 14), which are now in the Museum of Comparative Zoology at Cambridge. After comparing with them our specimens from Indiana, and several from Burlington, we became convinced that the consolidating plates, as we had called them, consist not of five but of seven plates, one to each of the four regular interradii, and three to the posterior one. Of the three latter plates, the middle one is larger, and occupies the space between the ambulacra and the ventral tube, the other two being altogether subambulacral. The middle plate, which we find in most excellent preservation in the Indiana specimens, is not covered by other plates, but is throughout profusely perforated, in a somewhat similar manner as the madreporite of other Echinoderms, and in our opinion, must have performed similar functions.

Considering now that in *Cyathocrinus iowensis*, and in the other Subcarboniferous Cyathocrinidae in which the "madreporite" is represented, the tube is imperforate, and that, on the contrary, in *Euspirocrinus spiralis* the whole space which in other forms is occupied by the madreporite, is taken up by the ventral tube, and that this is profusely perforated, it seems natural that the single plate of the former should have performed the functions which in the latter

were discharged by the tube. This is further probable, if it is true that the ventral tube is the greatly extended posterior area of the ventral disk, and that the "madreporite" represents not the proximal plate of that area but the distal one. The first row of interradials of the posterior side in all Crinoids in which there is either a ventral sac or proboscis, rests upon the special anal plate, if such is present, and hence this cannot be located in a *Cyathocrinus* at the ventral side of the calyx, but must be looked for at the base of the tube facing the dorsal cup. This, it seems to us, proves conclusively that the perforated plate is a true anambulacral plate, analogous with the perforated limestone particles at the disk of recent Crinoids, and not a first interradial. Neither can we regard the two narrow pieces at either side of the "madreporite" as true interradials, for if they represented, as might be supposed, the posterior interradial split into two halves by the madreporite, they should rest like the middle one against the anal plate. They are strictly subambulacral, supporting one-half of the two posterior ambulacra, the other half resting upon the incurved lateral margins of the adjoining larger plates. This seems to suggest that not only the two smaller plates but possibly also the four larger ones, wholly or in part, are subambulacral plates, and this is not so improbable as it might seem at first sight, if we remember that these parts in all Cyathocrinidae, perhaps with the exception of *Euspirocrinus spiralis*, are covered by other structures.

We have stated before that the "consolidating plates" of *Cyathocrinus* were regarded by us and Dr. Carpenter as closely similar to, if not homologous with, the deltoids of the Blastoidea. In both these groups the plates are laterally connected, and partly covered by the ambulacra so as to be in part subambulacral; but, while in the Cyathocrinidae generally the middle or deltoid part is concealed by perisome, it is more or less exposed in the Blastoids. The similarity that exists in the structure of these plates between the two groups is best observed by a comparison with *Pentremites*. In this genus, the deltoid part is heavy, and differs quite distinctly from the concealed subambulacral portions, which are comparatively delicate.

*Pentremites* has also an interambulacral integument of small plates overlying the upper portions of the deltoids, which either are spinous themselves or covered with spines,[1] and we cannot help think-

[1] The Summit Plates in Blastoids, Crinoids and Cystids, and their Morphological Relations, by Charles Wachsmuth and Frank Springer (Proc. Acad. Nat. Sci. Phila., 1887, pp. 9 to 11).

ing that these plates represent morphologically the perisomic plates which cover the so-called interradials of *Cyathocrinus*.

Now, is it not possible that the deltoids are compound structures, and the concealed parts were originally separate subambulacral plates, which in palaeontological times became anchylosed with the deltoid part to give more strength to the calyx? This seems quite probable if we consider that a fusion of two or more plates often takes place among Crinoids, and that *interradial* plates, as the term denotes, cannot be *subambulacral*. Such, indeed, also might have been the case in *Euspirocrinus* in which the interambulacral parts are large and apparently not covered by perisome. It is in this regard very significant that in Blastoids with large deltoids, such as *Elaeacrinus* and *Schizoblastus sayi*, it appears from the ornamentation as if the deltoids originally might have consisted of three parts which afterwards had been anchylosed, and Lyon (Kentucky Geol. Rep., p. 489, Pl. V, fig. 1*b*), has actually described interradials in *Elaeacrinus*. In this genus we find generally upon the surface of the deltoids, parallel with the ambulacra, a short distance from them, raised lines, and all striations toward them from the ambulacra are horizontal, while those between the lines take an upward course. This feature is so universal and conspicuous, that it probably is more than mere ornamentation. Such striations upon the plates are more or less the result of growth, and this would seem to indicate, that the growth of the plates took place independently in different directions, and that the parts in question are morphologically distinct. The ambulacra of *Elaeacrinus* are narrow, and it is quite possible that in this genus the "subambulacral" pieces enclosed an interradial in the way we suggested; but that in *Cyathocrinus* they abutted laterally so as to form a support for the disk. This of course is as yet simply hypothesis and has to be substantiated.

The ventral sac of the Cyathocrinidae rarely, if ever, reaches the tips of the arms. It is closed at the upper end, and composed of vertical rows of hexagonal, rather short and solid pieces, which are so arranged that the plates of adjoining rows alternate with one another. The anus is placed near the top facing anteriorly, and closed by a small pyramid of five or six triangular pieces, resembling those of the Cystids and *Stephanocrinus*.

The tegmen of the Hybocrinidae is similar to that of the Cyathocrinidae, but the posterior interambulcral area rises but little above the level of the four others. The ambulacra are tegminal, and ap-

parently rest upon the lateral margins of the five large plates. There are no orals, the median portions of the disk being occupied by large covering plates. The anus is closed by a pyramid of six or more pieces, surrounded by numerous irregular smaller plates.

The ventral pavement of the Anomalocrinidae, which we have observed in a fine specimen from the Museum of Comparative Zoology at Cambridge,[1] is very different from that of the Cyathocrinidae. It consists of rather large, moderately thick, irregular pieces, five or six deep, which decrease in size toward the center and cover the peristome, there being no orals or consolidating plates. The outer plates rest against the large incurved limbs of the radials, which form a wide and deep sinus at the upper face of the calyx for the reception of the ambulacra, which come out *beneath* the irregular calyx plates above, as beautifully shown in the specimen. Not only are the ambulacral plates on a lower level than the disk plates, but they are also of a different shade of color, which makes the case more instructive.

In the Poteriocrinidae, the ventral pavement has never been found in perfect preservation. We have dissected a number of finely preserved specimens, but only in one instance found small fragments of the tegmen *in situ*, which indicate that it consisted of very small delicate pieces. The plates of the ambulacra must have been also extremely fragile, for with the exception of the one instance above mentioned, we never found them preserved either upon the disk or upon the arms, owing probably to the absence of any consolidating apparatus. The form and size of the ventral sac is extremely variable in this group. In some genera it extends beyond the tips of the arms, in others consists merely of a short cone, in some of them it is tubular, in others club-shaped, in some balloon-shaped or coiled up, the sides of the whorls connected or free; but in all cases, so far as known, the plates are arranged in vertical rows which sometimes diverge at intervals, and in all of them the edges of the plates—not their substance—are perforated by pores or clefts. The anus, wherever it has been observed, is located at the anterior side of the sac, and generally well down toward the bottom.

[1] Prof. Alex. Agassiz has given us the unrestricted use of the magnificent Crinoid collections of the Museum of Comparative Zoology at Cambridge, containing several of the finest original and typical collections ever made from different formations, both in this country and Europe. Only those who are acquainted with the extent and variety of the material thus brought together can appreciate the obligation under which his liberality has laid us.

A similar porous sac is found in the Heterocrinidae and Belemnocrinidae, but nothing is known of the other plates of the disk.

Among the Encrinidae, a ventral pavement has been discovered by Wagner (Zeitschr. d. Deutsch., Gesellsch., 1887, pp. 822 to 828). The pavement, as we infer from his description, rests against the radials, whence it rises to about the height of the third brachials, where it contracts abruptly to one-half its diameter at the base, and is surmounted by a sort of cone. The peripheral part consists of small limestone particles or irregular plates, and is decidedly flexible; while the conical part, which is composed of larger plates, is more or less rigid. Nothing is said about the ambulacra, which probably were not visible in the specimen. That the cone represents a short ventral sac, and that the Encrinidae must be classified with the Fistulata, as we have always maintained, is clearly shown from Wagner's description.

A somewhat similar disk has been observed by De Loriol in *Apiocrinus roissyanus* (Paléont. Française., 1st serie, Anim. Invertebr., Crin., p. 272), a species which is here of especial interest as having plates interposed betweeen the rays. These plates, which are large, extremely heavy, and apparently rigid, were regarded by Carpenter as true "calyx interradials." Upon this we criticised him (Revision, Pt. III, pp. 63, 72 and 137), as it appeared to us the plates must represent morphologically the same thing as the smaller plates between the rays of the Pentacrinidae and Comatulidae. They occupy not only a similar position, but also join with the plates of the ventral disk in a similar manner. A structure parallel to that of *Apiocrinus roissyanus*, we find in most of the Ichthyocrinidae and in *Guettardicrinus*. The interradials are large and heavy, rather regularly arranged, and it was the superficial resemblance that led Dr. Carpenter to regard them as homologous with the calyx interradials of an Actinocrinoid, and as morphologically distinct from the plates between the rays of the Comatulidae. This leads to the question what are "calyx" and what "disk"—interradials? The former term was introduced by Carpenter, but so far as we know, never explained by him.

It has been our impression that in all Crinoids with a vault, *i. e.*, all forms in which we supposed we found a subtegminal disk, or had reason to postulate a disk from analogy, the plates between the rays invariably were "calyx" interradials; and, on the contrary, in those Crinoids in which the disk itself formed the surface, all plates between

the rays were perisomic. We arrived at this conclusion after discovering that the interradials of the Camerata are continued into the "vault," and supposed that underneath them there was another system of skeletal plates which, like the former, extended from the *upper margin of the radials up to the orals.* It was upon these grounds that we held the interradial plates of *Apiocrinus* and *Guettardicrinus* to be enormously developed perisomic plates, and upon the same principle we called the corresponding plates in the Ichthyocrinidae perisomic, as soon as we had found an open mouth and a true disk in *Taxocrinus.* The "calyx interradials," we thought, formed an upward prolongation of the dorsal cup, and the perisomic plates a downward extension of the disk, as was practically done by Carpenter in the case of the Pentacrinidae and Comatulidae, and in the Palaeozoic Reteocrinidae and Platycrinidae; while in other groups he seems to have been of the opinion that the "calyx interradials" are followed sometimes by vault—and sometimes by disk plates. In *Thaumatocrinus* he calls the large plates between the radials "calyx" interradials, and the smaller ones above perisomic plates. In *Glyptocrinus* it appears that he regarded the plates between the rays as "calyx" interradials and those of the dome as perisomic. In the Actinocrinidae, however, he thought the "calyx" interradials to be followed by a vault. All this indicates that in these groups Carpenter was influenced largely, if not altogether, by the size of the plates and their regular or irregular arrangement. He regarded the plates as "calyx" interradials and vault pieces, respectively, when large and regularly arranged, but as perisomic plates when small and of ill-formed boundaries. We allude to these facts to show that neither the small size of the plates, nor the presence of ambulacra upon the surface, are good criteria to make them perisomic plates. That there exists, however, a close resemblance in some of these forms with some of the perisomic plates of recent Crinoids, we are quite ready to admit, and in pointing this out, Dr. Carpenter, no doubt, laid the foundation for a better understanding of those structures; but he did not go far enough. He overlooked that among palaeozoic and recent Crinoids are found all intermediate stages from the membranous disk of *Antedon* to the solid vault of an *Actinocrinus* or *Batocrinus*, and this fact has led us to enquire whether all interradial and "vault" plates are not perisomic.

Ever since we discovered that the ventral surface of *Taxocrinus* is a true disk, we became convinced that the views heretofore held by us respecting vault and disk, must be greatly modified or altogether abandoned. We have since given considerable thought to the subject, and in the latter part of last year laid the results before Prof. Alex. Agassiz and Dr. Carpenter, who both encouraged us to continue our researches in that direction. Prof. Agassiz informed us that he had come to quite similar conclusions respecting those plates from his own studies, and Dr. Carpenter with his usual liberality gave us valuable hints and explanations, and now agrees with us on this question in all essential points.

The ventral pavement of the Camerata is composed of interradial plates which, as before explained, form a continuation of the plates from the dorsal cup, and these meet with the orals, where they are represented. Frequently also the covering plates of the ambulacra take part in the pavement, and a set of plates to which we gave the name "radial dome plates." As the latter plates were supposed to form an integral part of the vault, overlying the ambulacra, they deserve especial attention. They were regarded by us, and also by Carpenter, as the actinal representatives of the radials, but later investigations have shown that they are highly differentiated covering pieces. The plates appear in two forms. They are either followed by series of covering pieces, and pass out from between two orals, as in most species of *Platycrinus*; or they are in a certain sense isolated plates, surrounded by other "vault" plates, and succeeded by similar plates of higher rank, as in the case of the Actinocrinidae with subtegminal ambulacra. The former case is quite readily perceived if we examine the Silurian forms, in which, when their ambulacra are exposed, two regular series of alternating plates pass outward directly from the orals. Here either the radial dome plates are wanting, or they must be represented by the proximal covering plates. In the later Platycrinidae, the covering plates throughout lose much of their original character, being, as a rule, more extravagantly developed than in the earlier forms, and the proximal plates of each ambulacrum are larger than the succeeding ones, so as to obscure the alternate arrangement.

The "radial dome plates" of the Actinocrinidae and allied forms are generally larger than any of the surrounding plates, often nodose, and sometimes extended into long spines. They are not followed by covering pieces like those of the Platycrinidae, and, unlike them,

are located at some distance from the orals, being placed in the simpler forms, with but two arms to the ray, close to the outer margin of the vault (*Agaricocrinus*), directly over the point at which the bifurcation of the ambulacra takes place. When there are four arms to the ray, they are removed relatively further inward, and are followed by two similar but smaller plates; but when there are three arms to the ray by one plate only, which is directed to the side of the bifurcation.

It is now very interesting to find also that the axillary plates of the covering pieces upon the ambulacra are frequently protuberant. In *Eucladocrinus millebrachiatus* all along the free appendages they are strongly nodose, and their tops, if the ambulacra were subtegminal, would naturally extend into the vault, and be exposed to view. That all calyx plates, and especially the "radial dome plates," were capable of secreting an enormous amount of limestone matter, is well shown by the fact that in some species of *Dorycrinus* the plates are extended to the length of three or four inches, and their ends, if accidentally broken during the life of the Crinoid, were at once replaced. Our explanation that the radial dome plates were developed from the covering plates, seems to us exceedingly probable, and has been favorably received by Dr. Carpenter. If the plates were special structures covering the ambulacra, as heretofore supposed, they would have to be regarded as true vault plates.

In many of the Palaeozoic Crinoids we find upon the tegmen elevations, which sometimes take the form of ridges and pass out from near the center to the arm bases. These ridges which are best preserved and most frequently found in Silurian Camerata, are formed either by the covering plates, or by the so-called smaller vault pieces which pass up from between the rays. Similar ridges occur upon the disk of recent Comatulidae, but these are always formed by the covering pieces, and the plates are movable; while in Palaeozoic forms, in which covering plates enter the surface, these are united by a suture. Ridges of this kind are found in *Actinocrinus quinquangularis* Angl. (Iconogr. Crin. Suec., Pl. XVI, fig. 28), *Habrocrinus ornatus* (Ibid., Pl. XXVII, fig. 5), *Marsupiocrinus depressus* and *M. radiatus* Angl. (Ibid., Pl. X, figs. 16 & 21), and *Platycrinus symmetricus* W. & Sp. (Proc. Acad. Nat. Sci. Phila., 1888, Pl. 18, fig. 15). The mouth in these species is closed either by the orals, or, when these are absent, by the uppermost covering pieces, which interlock with those of adjoining rays. Very prominent ridges occur al-

so upon the disk of the Ichthyocrinoid genus *Taxocrinus*, as shown by our figure in the Proc. Acad. Nat. Sci. Philadelphia, 1888, Pl. 18, fig. 1*e*. In this genus, contrary to the preceding forms, mouth and food grooves are opened out, but otherwise its ventral structure agrees so closely with that of the young *Platycrinus symmetricus* that it seems as if there could be no doubt that the two integuments are composed of the same elements. Indeed, a slight receding outward of the posterior oral, and movable covering pieces, would place the two forms essentially in the same condition. It would seem to suggest further from analogy, that in all other groups in which the ambulacra are exposed very similar conditions prevail, and that in all those forms, as in *Taxocrinus*, the ventral surface is a disk. So far we have met with no serious difficulties, but they arise when we consider those forms in which the ambulacra enter the surface at a point from beneath the interradial plates.

If there was in these forms, as heretofore supposed, a system of skeletal plates distinct from the disk, which cover the ambulacra and the disk generally, it would seem to follow that the upper interradials, which surround the orals and cover the ambulacra, must be vault plates, and all lower ones, so far as the ambulacra are exposed, disk plates.

Cases in which the calyx ambulacra pass out from beneath the interradials before they enter the arms, are found in different families of the Camerata. They occur more frequently among Silurian than among the later Crinoids, and generally in forms in which the ventral surface is paved by small irregular pieces, such as *Glyptocrinus*, *Reteocrinus* and *Archaeocrinus*, but also occasionally among Subcarboniferous forms. A most instructive case of this kind is represented by a rather young specimen of *Megistocrinus nobilis*, in which not only the covering plates, but also well developed side pieces enter the calyx. The ventral side of this species consists of moderately large, irregularly arranged plates, which gradually decrease in size toward the arms. The tegmen is perfectly flat except near its outer margin, where it is distinctly plicated to form the large openings for the ponderous arms. At the flat inner portions the ambulacra are concealed, but along the plicated outer part the covering plates and side pieces are in sight for some distance, and the interradial dome plates extend only to the lateral margins of the ambulacra. It is now quite instructive that in another, more adult specimen of this species, those parts of the ambulacra which in the former specimen

were exposed, are roofed over by an extension of the interambulacral plates of subsequent growth. This incidental observation is very important, as it throws much light upon the development of the so-called vault of the Camerata generally. It shows that the same system of plates, which in a young specimen is *inter*-ambulacral only, may gradually become *supra*-ambulacral in another.

A somewhat different structure we observed in a finely preserved adult specimen of *Megistocrinus evansi*, in which in three of its rays two series of large, nodose alternating plates pass out from near the orals in the direction of the ambulacra. The series are frequently interrupted by small, flat pieces, passing out from the interambulacral spaces, and these intermingle with the larger ones. At some places the arrangement of the larger plates, which evidently are covering pieces, is as regular as in any *Platycrinus*, but at others owing to the interference of the smaller plates, quite irregular, especially in the two rays to the right of the anus, in which scarcely any two of these plates are continuous. It is most remarkable that in no two specimens of this species is the arrangement of the covering pieces alike, and in some of them only the five large bifurcating plates, the so-called radial dome pieces, are in view, which are followed by ten others of a second order; these, however, are always represented. The ventral structure of this species offers not only a most excellent proof that the so-called radial dome plates, as suggested before, are extravagantly developed covering pieces, but indicates also that the "vault" was formed by a gradual extension of the interambulacral pieces toward the ambulacra, either covering the latter entirely, or intruding upon them, leaving the more prominent plates exposed.

In *Glyptocrinus* and *Reteocrinus* the tegmen is essentially in the same condition as in *Megistocrinus nobilis*, but the plates are smaller, and in the absence of orals nearly the whole surface is covered by small granular plates, including the central portions. Toward the periphery there are ridges leading to the arm bases, but these are not found at the middle part, where the surface is evenly convex. Only on top of these ridges, that is, in close proximity to the arm bases, are the covering pieces exposed. They are quite regularly arranged in two rows, and so well defined that we doubt if it is possible that they were continued further up along the surface, as suggested to us by Dr. Carpenter, or they would be recognized in the specimen. It seems to us more probable, and almost certain, that

they were exposed only to near the upper ends of the ridges, and then followed the inner floor. If this interpretation is correct, *Glyptocrinus* represents another instance in which a sort of vault is formed by the lateral extension of the interambulacral system of plates.

An examination of the different tegmens which occur in the various families of the Camerata, leads to the conclusion that the ambulacra, as a rule, are subtegminal in specimens with a high dome and bulging at the arm bases; but are generally tegminal, or become tegminal before entering the arms, in species with a flat or depressed surface. They are also exposed in species with high ridges, and in those in which the arm openings are directed upwards, a structure which necessitated a rising of the ambulacra toward the arms. The presence or absence of the ambulacra upon the tegmen, therefore, is not, in our opinion, an essential structural feature in itself, but is rather a consequence of differences in the form and construction of the tegmen in the respective species. This explains in a natural way why the ambulacra are exposed in forms like *Actinocrinus quinquangularis*, *Habrocrinus ornatus*, *Marsupiocrinus depressus* and *Glyptaster ornatus*, all of which have a more or less flattened ventral surface, and conspicuous elevations reaching up to the orals, and why in the typical *Actinocrinus* with a high conical dome the ambulacra are subtegminal, but tegminal in the depressed *Actinocrinus stellaris* which approaches the condition of the Platycrinidae. In *Platycrinus* the tegmen is rather flat in all elongate species, and all have more or less high ridges. The latter we find also in the short discoid species with an elevated dome, owing probably to the shortness of the dorsal cup. The condition of the ambulacra in *Platycrinus* may also be due partly to the extravagant development of the plates.

Comparing the earlier Melocrinidae and Actinocrinidae with those from the Devonian and Subcarboniferous, it is seen that they are built substantially on the same plan. Among the latter the ambulacra occasionally form a part of the solid test; while in by far the majority of their species they are kept below. The plates in all of them occupy relatively the same position to surrounding parts, the only perceivable difference is that those of the later forms are somewhat larger and heavier, which is readily explained by palaeontological development. Why then should their tegmen be composed of a system of plates morphologically distinct from that of the others?

In *Glyptocrinus* and *Megistocrinus*, a sort of vault is formed by the greater development of the interambulacral plates and their gradual fusion along the line of the ambulacra, and from that it would seem to follow that similar modifications took place also in the later forms if it was not for the supposed disk at the inner floor of some species of *Batocrinus*, *Actinocrinus*, *Physetocrinus* etc. As to this structure we have recently made some very important observations.

Through the kindness of Dr. Horace G. Griffith of Burlington, to whom we are indebted for many favors, we obtained a most instructive specimen of *Physetocrinus* showing the structure along the inner floor of the tegmen in a most excellent preservation. This specimen has the great advantage of being free from any silicious coating, such as obscured the structure in all former specimens of this kind. The outer surface of the tegmen is composed of moderately large, smooth pieces of irregular form, closely fitted together at all sides. There are no orals, but near its outer margin there are "radial dome plates" of a first and second order, which are readily recognized by their larger size and greater convexity; but besides these no other covering pieces are visible. Looking at the inner floor, we find the same arrangement of plates, and actually the same plates, but their general aspect is totally different. They appear as sharply delineated stars, with as many rays as there are sides to the plates. There are abrupt depressions between the star-rays, which on meeting the corresponding depressions of adjoining plates, form deep, sometimes cavernous pits, more or less undermining the plates; and there seems to be but little doubt that the pits communicated with one another by imbedded passages all along the tegmen. The star-shaped plates extend over the peristome as well as over the ambulacra, but are occasionally interrupted by small, irregular supplementary pieces, apparently solid. The structure shows plainly that the tegmen of *Physetocrinus* is not composed of two distinct sets of superimposed plates, but of one set only, which are solid externally, and more or less perforated or porous at their inner portions. That there is but one set of plates is further confirmed by the position of the ambulacra which, as shown by the specimen, follow the inner floor. The latter is of the utmost importance, for, if the upper or solid part, as was supposed to be the case in the allied *Batocrinus* and *Actinocrinus*, represented a vault, and the inner part a disk, the ambulacra, if placed beneath the latter, would be covered by two integuments, at first by the overlapping interambulacral plates,

and again by a vault, which is exceedingly improbable. The ambulacral skeleton itself is not preserved in the specimen, but the place it occupied is clearly indicated by shallow grooves, which are formed by the thickening of the plates all along the interradial spaces.

The internal structure of *Physetocrinus* gives us the key to that of *Batocrinus*, *Dorycrinus*, *Actinocrinus*, and *Teleiocrinus*, in all of which, we are no longer in doubt, there is but one integument, and the part which we had heretofore regarded as the disk constitutes the poriferous portions of the plates. That in these forms the respective parts are continuous, connected by small surfaces or pillars, was pointed out by us in the Revision (Pt. II, pp. 26–27, and Pt. III, pp. 60 and 61). We gave there a full description of the pores and imbedded passages "evidently for the free circulation of water"; but misunderstood the relations of the ambulacra to surrounding parts. We then supposed that the sharp, slightly overhanging edges of the interradial partitions, along the sides of the ambulacra, were closed beneath them; which proves not to be the case. The ambulacra in all specimens in which they have been preserved, are visible from within the calyx.

The inner structure of these Actinocrinidae always reminded us of the double test in the Clypeasteridae, in which the two parts are connected by similar pillars, and we think it highly probable that we have here among these Crinoids a complex vascular water system, which extended all the way up from the interradial plates of the dorsal cup to the upper end of the ventral disk. Such a complex system was not necessary in recent Crinoids in which the whole ventral surface is perforated, and the water could be brought in contact with any part of the body, but the case is different in the Camerata, in which the tegmen is almost perfectly solid.

There are good reasons to believe that in the Camerata the water was introduced near the arm bases through small openings, described by us (Revision, Pt. II, p. 51), as respiratory pores, and then followed the canals and passages along the test. We have observed such openings not only in the Actinocrinidae, but also in the Melocrinidae, and Rhodocrinidae. In the genus *Dolatocrinus* they are slit-like as in Ophiurids. Like the round openings of *Batocrinus* and *Actinocrinus*, they are located between the rays and their main divisions, a little above the arm region. Some species have from 4 to 6 of these slits to each interradius, and 2 to 4 to each interdis-

tichal space, all arranged horizontally. In *Dolatocrinus* the vascular system probably extended only over the peripheral portions, the upper portions at the inner floor of the tegmen being perfectly smooth. In *Batocrinus* and *Teleiocrinus* it passes up to the outer margins of the orals; while in *Physetocrinus*, in species in which the orals are unrepresented, it extends over the whole inner surface.

The subtegminal anal tube of *Siphonocrinus* is yet unexplained, and we freely admit the structure is still a puzzle to us, but in the absence of specimens showing the test (we know it only from natural casts), we abstain from any speculation respecting it. It should be said, however, that in *Siphonocrinus nobilis* the tube passes out centrally—not anteriorly—which leads to the conclusion that the ventral structure of *Siphonocrinus armosus* cannot have been essentially different from that of the other Camerata. The so-called subtegminal anal tube is probably the extended hind gut, which passed over the mouth and portions of the ambulacra. It appears from the impressions upon the casts that the individual plates, which cover the ambulacra and surrounding parts, extend also over the "proboscis."

From the foregoing facts it appears that *Batocrinus*, *Physetocrinus* and allied forms likewise had but one integument covering the body, that the structure which was supposed to represent the "vault," is composed merely of the outward growth of the plates constituting the disk, and that the plates are thickened and project in "T" shaped extensions.

It will be remembered that it was upon these forms mainly that we postulated the presence of a vault in all Camerata, but now, if it is true that even these have no further integument covering the disk, it seems to us conclusive evidence that a vault as a special structure does not exist in any Crinoids whatever, and that the tegmen in all of them is a greatly modified disk.

A comparison of the earlier with the later Camerata shows that in Silurian forms the ventral surface, as a rule, is covered by small, irregularly arranged plates; that these gradually increase in size in the Devonian, and attain in the Carboniferous that extravagance of form, which in the Batocrinites and Actinocrinites reaches its culmination. With regard to the ambulacra we have observed that in the earlier forms they are much more frequently exposed, their covering pieces are smaller, more regularly arranged, and not so highly differentiated as in the later ones. Their disk generally resembles that of recent Crinoids, and if it were not for the sutural

union of the ambulacral and interambulacral plates, and the closure of mouth and food grooves, the conditions of the two structures would be almost identical.

From these observations we conclude that the heavy plated, extravagantly developed integument, the so-called vault, was gradually evolved in geological times from the thinly plated disk of earlier forms. This may have been accomplished in the following way: At first the ambulacra were exposed at the surface, but subsequently became covered over by the great development of interambulacral plates, which encroached upon their space at the surface from each side, and finally closed in above them, crowding the ambulacral skeleton inward. In species in which the ambulacra are not covered but remain external, the covering pieces were stronger and offered greater resistance, so that instead of being crowded inward they became incorporated into the test.

Dr. Carpenter has suggested to us in a note a somewhat similar case—though he thinks the parallel must not be carried too far—in the gradual obliteration of the ambulacral grooves in some arms of *Actinometra*, where the convex perisome gradually encroaches more and more on the sides of the groove, bringing its edges together, and finally closing it. It seems to us that this is a very significant illustration of what may have happened in the evolution of the closed "vault" from the open disk.

Returning again to the *Inadunata*, we find in the Fistulata the palaeontological development essentially different from that of the preceding group. The plates of the ventral side of the calyx at no time attain the rigidity and large size of those in the Camerata. The plates of the dorsal side, with the exception of the anal plates, which we consider afterwards separately, undergo scarcely any changes, and the brachials in all of them are free plates from the radials up. The ventral sac in some of the earliest forms is quite small, but rapidly attains enormous dimensions, constituting the greater part of the calyx; but at the end of the Carboniferous period dwindled down almost as rapidly again to its former insignificance, so as to be represented in *Cromyocrinus*, *Eupachycrinus*, *Erisocrinus*, and *Encrinus* only by a short cone. Respiration was effected directly through the test, but apparently only at the posterior side of the calyx, either by means of pores along the ventral sac, or by a madreporite placed anteriorly to the sac. The ambulacra of all Fistulata, so far as known, are tegminal; they are bordered by side pieces,

and the food grooves are roofed over by covering plates, which were apparently immovable. The mouth was probably closed in all of them.

In the recent *Holopus*, *Hyocrinus* and *Bathycrinus*, the ventral sac is further reduced, so as to be a mere proboscis or anal tube. In all of them the interambulacral plates themselves are perforated and not merely their margins, and mouth and food grooves are exposed.

The *Inadunata Larviformia*, as now restricted, have neither interradial nor interambulacral plates, and rarely anals, and their orals cover the ambulacra to the bases of the arms. They have apparently no water pores, in the calyx, and it is very possible that throughout this group water for respiration was introduced through pores at both sides of the arm ambulacra, as suggested already by us (Revision, Pt. III, p. 83).

The *Articulata*, the third great division of the Crinoidea, to which we have heretofore referred only the Ichthyocrinidae, will probably have to be amended so as to include the Comatulidae, Pentacrinidae, Apiocrinidae and Bourgueticrinidae. How closely the Comatulidae are related to the Ichthyocrinidae may be seen by comparing the simpler forms of the latter with the young *Antedon* in its pedunculate state (Chall. Report on Comat., Pl. XIV). The stem in fig. 3 is exactly like that of *Mespilocrinus*, fig. 9 might represent as well a young *Onychocrinus*, and the brachials of fig. 5, in their waving sutures are quite characteristic of the Ichthyocrinidae generally. In all of these families the proximal brachials are incorporated into the calyx, either by supplementary plates, by soft tissues, or by sutural union.[1] In some species of the Apiocrinidæ and Ichthyocrinidae these supplementary pieces are quite large and massive, and some have a sort of regularity in their arrangement, but they are notwithstanding perisomic plates. The ambulacra throughout this group are tegminal, although the plates are frequently not readily

[1] In some specimens of *Millericrinus* it appears in the fossil as if their brachials might have been free from the radials up; but we doubt it, as the capacity of the calyx is too small to have contained the whole of the visceral cavity, and it seems to us more probable that the lower brachials were connected by small plates or soft tissues. A lateral union of the brachials, such as we find frequently in the Apiocrinidae, and which occurs also in the Ichthyocrinidae, has never been observed in any of the Camerata at least not between costals or distichals. In some Actinocrinidae sometimes the higher brachials are laterally connected.

distinguished from the interambulacral plates, and the mouth, so far as known, is exposed.

It thus appears that in the Inadunata and Articulata, as in the Camerata, there is but one integument covering the body, and that the ventral pavement, although undergoing various modifications in geological times, is a true disk. We, therefore, abandon the term "vault" as a morphological term altogether, and consider all plates between the rays and interposed between the ambulacra, as well as those covering the ambulacra when these are subtegminal, as plates of the disk.

We think the plates of a Crinoid fall naturally into two categories, viz. *primary*, and *secondary* or *supplementary* pieces. The primary plates form the fundamental part of a Crinoid, while the supplementary pieces serve to fill up spaces. The primary plates may be separated into two classes: those developed on the right antimer, which in one way or another are related to the axial nerve cords, and those developed on the left antimer, and connected with the mouth or the annular vessel around it. To the first class we refer the stem joints, basals, underbasals, radials, all brachials whether fixed or free, and the plates of the pinnules; to the second the orals and all plates of the ambulacra to the end of the pinnules. The remaining plates, which embrace the various perisomic plates, are supplementary pieces, and in our opinion neither strictly actinal nor abactinal.

Dr. Carpenter, in the July number of the Ann. and Mag. Nat. Hist., p. 12, shows that, in analogy with other Echinoderms, there is fundamentally but one ring of radials in a Crinoid, and that the succeeding plates along the rays are brachials, a view which we have held for some time, and discussed in various parts of our Revision. After correspondence with us and mutual discussion, he brought out special terms for the different orders of brachials. He proposed the term *costals* for the primary brachials, *distichals* for the plates of the second order, *palmars* for those of the third, *post palmars* for those of the next order. To the arm plates after the last bifurcation he applies the term *free brachials*. To the most of this terminology we entirely agreed, but in some particulars it does not quite meet the requirement in dealing with the greater complexity and variety of construction found in the Palaeozoic forms. We find it more convenient to use the term *brachials* in its general sense, to designate all plates of the rays succeeding the radials. They will be *fixed brachials* so far as they are incorporated into the calyx, and *free*

*brachials* when they are not. In either case they will also take the special appellation given by Carpenter, viz., *costals, distichals, palmars* etc., which will be either *fixed* or *free* as the case may be. We prefer to use the term *post palmars*, however, for all plates beyond the third bifurcation, whether there be further branching or not, and apply *free* to all brachials that are free from the calyx, so that in the Inadunata all plates beyond the radials are free brachials, whereas, according to Carpenter's idea, in a frequently dichotomizing form like *Cyathocrinus* the term would only be applied to the joints of the last slender branches at the tips of the arms. In the Camerata we will have one or more orders of fixed brachials, as the calyx extends variously to the distichals, palmars, or post palmars. To correspond with these terms and conform to the ideas of the foregoing discussion, it will be advisable to designate the different perisomic plates as follows:

*Interradials*, all plates interradially disposed in the calyx.

*Interbrachials*, a general term for all plates between the rays above the radials.

*Interdistichals*, the plates between the first divisions of the ray.

*Interpalmers*, those between the second divisions of the ray.

*Interambulacrals*, the plates between the ambulacra.

Let us now consider the anal plates, which take such an important part in the phylogeny and classification of Palaeozoic Crinoids. The term "anal plate" has been used by some writers indiscriminately for all interradial plates of the posterior area, while others restrict it to the plates directly or indirectly connected with the anus. We apply the term only to the latter plates, and only to those taking part in the dorsal cup. All others are plates of the anal tube or the ventral sac.

The anal plates in all Camerata, when present, occupy the median line of the posterior area so as to divide the interbrachial plates into two equal sets, and in rows containing an odd number splitting the middle plate into two pieces, even in cases when no anal plate is inserted between the segments. The latter is the case in all *Actinocrinites*, in which the first interbrachial row at the posterior side invariably consists of two plates as against one in each of the others; but all have an anal plate between the radials, and a second one in the second interbrachial row. In the *Batocrinites*, and in all other Actinocrinidae and Glyptasteridae, there are two interbrachial pieces above the first anal, which enclose a second anal piece. The Hexa-

crinidae, like *Cyathocrinus*, have but one large anal plate resting upon the basals. In the Eucalyptocrinidae there are no anal plates in the dorsal cup, and the five interradial areas are perfectly symmetrical. The same is the case in *Dolatocrinus*, *Stereocrinus*, *Centrocrinus*, *Allocrinus* and *Patelliocrinus;* while the typical Melocrinidae have an anal plate in one or more of the upper rows. In the Rhodocrinidae the anal plates are in a similar condition as in the Melocrinidae, their posterior area being undisturbed in some of them, while in others a few anal plates are introduced; but the Rhodocrinidae have at all five sides a plate interposed between the radials, which rests upon the basals. The Platycrinidae have no special anal piece, but the middle plate of the first row at the posterior side is considerably larger, and obviously served throughout this group as anal plate.

It appears from these observations that the distribution and position of the anal plates varies considerably among the families, and that in some of them they are absent altogether. As a general rule, the anal plates are well represented in species with a strong tube or a protruding lateral opening; while in forms in which the anus is central or comparatively small, as in the Eucalyptocrinidae, they are either wanting or but feebly represented. The interposition of the anus affected more or less the whole posterior area. In species with a large anal tube, the increase in width thereby produced necessitated the introduction of special anal plates; while when the tube was small, a mere enlargement of the regular interbrachial plates sufficiently increased the width of the area. This shows that the anal plates of the Camerata do not constitute a primary element, but are supplementary pieces, which were introduced as the case required. This is important as throwing light upon the anal plates in the other groups.

In the Fistulata the anals are the only plates interposed between the rays. They consist of one or two pieces, or are unrepresented altogether, and the ventral sac is supported by the radials. In species with but one anal plate, this rests upon the posterior basal, which is truncated for its reception, and hence is interradial in position. When there are two plates, as in most of the Poteriocrinidae, and in a few Cyathocrinidae, the second, which is actually the first or lowest in point of position, is placed obliquely to the right of the first, so as to encroach more or less upon the lower face of the right posterior radial, its lower angle resting between the upper sloping

faces of adjoining basals, its upper face supporting the first plate of the tube, which in some of these genera is partly enclosed in the calyx. To understand the relations of this plate, it is very important to note that throughout the various modifications which the posterior side of the Fistulata undergoes in geological times, this plate retains invariably its alternate arrangement with the basals. The plate, therefore, was radially disposed from the beginning, and always remained so. This shows that the widening of the anal area, which took place in later forms, owing to the increasing width of the ventral sac, was effected by a displacement of the arm-bearing plates. The oblique position, which the radially situated anal plate holds toward the posterior basal and the other anal plate, and this toward the first plate of the tube, gives to these plates a sort of alternate arrangement, which is continuous throughout the whole tube.

The relations of the anal plates in the various groups of the Fistulata were discussed by us at different times, and a comparison of the literature will show that our views underwent some modification in the course of time.[1]

The subject was also discussed by Dr. P. H. Carpenter in his paper "On the Relations of *Hybocrinus*, *Baerocrinus* and *Hybocystites*."[2]

We think it unnecessary to give a review of all these papers, and we can dispense with it more readily, as Mr. F. A. Bather, in an interesting paper "On the British Fossil Crinoids,"[3] has lately given a full history of them. We, therefore, take up the question where we left it in 1885.

Mr. Bather, in the paper above cited, has advanced views respecting the origin of one of the anal plates, from which we regret to be obliged to dissent. He agrees with us and Carpenter that the radial anal plate, the so-called azygous piece, constitutes primarily the lower portion of the right posterior radial, which in the earlier forms occupies a position immediately below the radial; but he differs from us essentially upon the origin of the other anal plate. He seeks to prove that this plate "originated as a plate morphologi-

[1] 1879, Revision, Pt. I, pp. 71 and 72; 1883, Amer. Jour. Sci., Vol. XXVI, pp. 365 to 377; 1885, Revision, Pt. III, Sect. I, pp. 11, 12 and 40; and 1886, ibid., Sect. II, pp. 196 and 210.

[2] Quart. Journ. Geol. Soc. London, Vol. XXXVIII, pp. 398–312.

[3] Ann. and Mag. Nat. Hist. (6th ser.), Vol. V, April, 1890, pp. 319–334.

cally corresponding to an ordinary brachial," which gradually in its palaeontological development passed down from above the radials to the basals, and between the radials. To the former plate he gives the name "*radianal*," which we think an excellent one, and we accept it as being more appropriate than azygous plate. To the latter he applies the name "*brachianal*," a term which becomes meaningless if the plate proves to be an interradial. For this plate we retain the name *anal plate*, as we hold it to be the true homologue of the anal plate in the *Antedon* larva, and the homologue of the *first* anal plate of *Actinocrinus*.

In our diagrams we have marked this plate X, and we find it convenient to refer to it as such in this paper. We apply the letter R to the radials, and when these are compound, we distinguish the lower, non-arm-bearing section as R'.

To understand the relations of the anal plates, we must at first direct attention to the structure of the radials of the earlier Fistulata, which in all *Lower* Silurian genera, probably with the exception of *Ottawacrinus*,[1] differ essentially from those of the *Upper* Silurian forms. It is very curious that in the former the radials in from one to three of their rays are compound, *i. e.*, constructed of two segments or parts, which are closely united by a horizontal suture, and in the organization of the Crinoid count as one plate. Compound radials are found in the Heterocrinidae, Anomalocrinidae, Hybocrinidae, and in the earliest Cyathocrinidae. In some of these families they are restricted to the right posterior ray, in others one or two of the other rays also may have compound radials. But we know of no case in which the compound structure extends to all five rays, at least two of the plates being always simple. Among the Heterocrinidae, as a rule, the right posterior and the right and left antero-lateral radials are compound—exceptionally the anterior one in place of the left antero-lateral—while *Anomalocrinus* and *Ohiocrinus* have but two, and *Iocrinus*, *Merocrinus*, *Hybocrinus* and *Hoplocrinus* only one. It is further worthy of note that when there are several compound radials, the corresponding parts are of nearly equal size; while the segments vary considerably among themselves in the

[1] *Carabocrinus*, which also we had referred to the Fistulata, is pos-ibly a Cystid. We were recently informed by Mr. Walter R. Billings that it may have hydrospires. He was kind enough to send us carefully prepared diagrams of this genus and of *Hybocrinus*, showing the structure of the ventral disk, for which he has our hearty thanks.

different genera. In *Heterocrinus, Ohiocrinus, Iocrinus, Merocrinus, Hybocrinus* and *Hybocystis*, the lower portions are considerably larger than the upper; in *Anomalocrinus* and *Dendrocrinus* the two are of nearly equal size; while in *Ectenocrinus* (*Heterocrinus*) *simplex* the upper ones are three to four times as large as the lower.

Now, what does this gradual increase of the upper portions, and the disappearance of compound plates in other rays than the posterior, tell us? Does it not indicate that in these Crinoids there is a gradual development from three to one compound plate, and from the compound to the simple radial? It certainly looks like it. The idea is further confirmed by the fact that true compound radials do not exist among any of the later Fistulata, in which, as we shall presently show, the lower portion of the right posterior radial, more or less, serves as an anal plate. But what preceded the compound radials? What else, but forms in which the arm-bearing portion was still smaller, and, primarily, those in which it was absent altogether, that is to say, was as yet undeveloped. This, indeed, seems to have been the structure of *Baerocrinus*. As we understand this genus, it has three well developed radials, and two are in a transition state, only their lower or non-arm-bearing segments being represented. This is further corroborated by the fact that the non-arm-bearing radials occur in the same rays as the compound radials of *Anomalocrinus*, for if we take the third plate of our diagram (Pl. X, fig. 6) to represent the posterior ray, the other non-arm-bearing plate must represent the antero-lateral one. This would make *Baerocrinus* the ancestral form, lower in its development than either *Anomalocrinus*, *Hoplocrinus*, or *Iocrinus*.

We now pass to the genera in which the lower segment of the right posterior radial serves as an anal plate. In all these forms, as may be seen in Bather's diagrams, the four other radials are simple, and in all of them the anal plate (X) is represented, and *invariably rests upon the basals*. The size of the ventral sac had rapidly increased at the close of the Lower Silurian, and the sloping upper faces of the radials were insufficient to support it. This required certain modifications in the structure of the dorsal cup. The posterior radials, which theretofore had been in contact laterally, now separated, the posterior basal increased its width, and the plate X was introduced to fill the space between the radials. While these modifications were going on, the radianal, or lower segment of the radial, retained its position between the upper sloping faces of two basals,

only changing its form enough to fit in between adjoining plates. Later on, as the ventral sac grew still larger, and the brachials came to occupy the entire upper face of the radials, leaving no surfaces for an attachment of anal plates, the right posterior radial was gradually shifted to the right, and finally attained a position directly above the right postero-lateral basal, and obliquely above the radianal. Toward the end of the Carboniferous, when the size of the anal tube was again reduced to a minimum, both anal plates gradually disappeared, and the five radials resumed their normal position.

Mr. Bather assumes, as before stated, that the anal plate, the plate X, is derived primitively from a brachial, which gradually in geological times passed downward into the dorsal cup. He regards (p. 329) "those forms as primitive in which the radianal is more of a radial and less of an anal, in which it is not in an asymmetrical position but corresponds to the other lower radial plates. Such forms are *Iocrinus*, *Heterocrinus*, *Ectenocrinus*, *Anomalocrinus* and *Merocrinus*. Now in all these forms X is supported by R and does not touch R'. Obviously then X is not derived from R', but originates above R, and on its left side. By parity of reasoning we assume the next stage to be represented in such forms as *Hybocrinus* (?), *Ottawacrinus*, *Dendrocrinus* and *Homocrinus* since in them R' is rather more asymmetrical. In these X has passed down from above R, and now rests with its lower half between the right and left posterior radials, being supported partly by R' and partly by the basal.[1] *Carabocrinus*, *Botryocrinus*, and similar forms are, as all acknowledge, the next stages in the shifting of the radianal; in these X has sunk still lower into the dorsal cup, and is now entirely in a line with the radials." "In *Parisocrinus* and *Euspirocrinus* among pinnuless forms, and in the Poteriocrinites, another change has taken place; the radianal has passed through a revolution of 90°, and the lowest plate of the ventral sac (t) has sunk down between R and X."

Before we enquire into the merits of this argument, we must ascertain whether the plates of the different genera which Bather marked X are structurally alike, for any mistake in this regard, naturally upsets the whole theory. The question is, is his plate X in *Iocrinus* and *Merocrinus* which rests upon that marked by him R or C, and that upon R' in *Hybocrinus* and *Anomalocrinus*, homologous with the plate of *Dendrocrinus*, *Homocrinus*, etc. supported by

[1] The latter is not the case in *Hybocrinus*, in which there is no anal plate supported by the basal.

R′ and partly by the basals, and homologous with the plate of *Poteriocrinus* which rests upon the basals and against the radianal? Bather did not discuss this question at all, notwithstanding we had expressed different views respecting his plate X in *Iocrinus* and *Merocrinus*. In both genera (in *Iocrinus*, as early as 1879, Revision I, p. 65), we called that plate a plate of the tube, and, so far as we know, never made any statement from which he might have inferred that we thought it represented the plate X in the other genera; yet Mr. Bather quotes us in his diagrams as if we had done so in 1879. We must also protest against his statement on p. 324. There, in summarizing our position on the anal question, he says under *Iocrinus*: "Radial growing larger at expense of Azygos, and here has *absorbed* X"; while the fact is we have always held, and have said so, that this plate X was *unrepresented* in *Iocrinus* and was as yet *undeveloped*.

Instead of commencing, as Bather did, with the earliest form, we prefer to begin with the simplest, and select as a starting point the genus *Cyathocrinus*, which is well known to every palaeontologist. *Cyathocrinus* has simple radials and but one anal plate, and this, as all writers agree, represents the plate X, and is the homologue of the first anal of the Actinocrinidae. Like the anal plate of the latter, it rests upon the truncated upper face of the posterior basal and between two radials, and supports generally three plates of the tube (Pl. X, fig. 4). The plate to the right sometimes rests against, or rather upon, the left sloping upper face of the adjoining radial, almost as in *Poteriocrinus*, but is here unsupported by a radianal. In *Graphiocrinus* also only the plate X is represented, but this is angular above, and supports two plates t, of which neither one is connected with the radials, but both are free plates.

In the preceding genera all radials, including the right posterior, are simple. In *Dendrocrinus*, however, the latter is compound. The anal structure of *Dendrocrinus* is most instructive as forming a sort of link between that of the earlier and later Palaeozoic Crinoids. Looking at *Dendrocrinus casei* (Pl. IX, fig. 12), it is obvious that the plate X holds the same relation to the compound radial, as X in *Cyathocrinus* to the simple one. It abuts against both segments of the plate, and is also supported by a truncate basal. In both, the plate X is succeeded by three plates in the tube, but in *Dendrocrinus* their arrangement is less regular, owing to the asymmetry of the radials. The plate to the right is placed at a

higher level than the one to the left, and does not touch X, nor does it touch the adjoining brachial, and is therefore a plate of the tube; while that to the left, which is laterally connected with the adjoining radial, actually forms a part of the dorsal cup. Both plates rest by their lower faces upon the sloping upper sides of adjacent radials, and each of them, as well as the middle plate—resting upon the truncate upper face of X—supports a vertical row of plates in the tube. These plates are not represented in Bather's diagram of *Dendrocrinus*, but are shown by our figure.

Now, if it is true that the plate which rests upon the left upper sloping side of the compound radial, represents morphologically the plate t in *Poteriocrinus*, and we think Bather will have to admit this, what then is his plate X in *Iocrinus* and *Merocrinus*? This plate, like t in *Dendrocrinus*, rests upon the left upper sloping face of the compound radial. Like that it is a free plate of the ventral tube, and like that it supports a vertical row of tube plates upon its upper face. The only real difference between these plates in the two genera is that the facet of the radial in *Dendrocrinus* is horse-shoe-shaped, and that of *Iocrinus* straight. This structure was evidently not understood by Bather, or he would never have called the radial of *Iocrinus* an axillary plate. There would be just as much propriety in calling the radials of an *Actinocrinus* axillary plates, for they support in a similar manner upon their upper sloping faces the first interbrachials.

Admitting that the plate X of Bather in *Iocrinus* and *Merocrinus* is a plate of the ventral tube, where is the anal plate? It seems to us there cannot be the least doubt that in both of them, and in most of the earlier Fistulata, the anal plate X is unrepresented. Their radials are in contact laterally, and the tube does not extend into the dorsal cup, but rests upon it. To satisfy ourselves that the plate t forms no part of the dorsal cup, we have examined and dissected a number of the most perfect specimens of *Iocrinus subcrassus*, and can state positively that it is a free plate of the tube. It is even perforated by lateral slits, such as occur frequently in the plates of the tube, but never in the true anal plate. The tube is club-shaped, narrow at the base, and its posterior side is composed of large, heavy plates, which are formed into a conspicuous ridge. From this narrow, arm-like ridge, as it appears from the outside of the specimens, one gets no idea of the real nature of the tube, which is quite deep and capacious.

After determining the structure of *Dendrocrinus* and *Iocrinus* the other genera are readily understood. *Anomalocrinus* is in a similar condition to *Iocrinus*, but has two compound radials in place of one. As in the case of *Iocrinus* the plate X is unrepresented. Its tube, which is narrow, rests within a notch formed by the sloping upper faces of the two posterior radials, the lower plate touching the first costal. Almost the same structure we find again in *Heterocrinus* and *Ectenocrinus* with three compound radials, and in *Hybocrinus* with but one. We cannot understand how Bather on p. 330 of his paper could conclude from the structure of *Ectenocrinus*, which he has regarded as one of the most "primitive forms," that X "originated as a plate morphologically corresponding to an ordinary brachial." His own diagram shows that his plate X in *Ectenocrinus* is placed symmetrically between the two posterior radials, resting as much on the one plate as on the other. In his diagram of *Heterocrinus bellevillensis* the plate is not correctly represented. A comparison with Walter Billings' figures (Trans. Ottawa Field Naturalist's Club, 1883), and ours (Pl. X, fig. 8), shows that it resembles in form and position that of *Ectenocrinus*, (fig. 9). Like that it rests upon the sloping upper faces of both posterior radials, and not on the plate to the right only. The plate in *Hybocrinus* occupies almost the same position, and we confess we fail to see how the structure of either of these genera helps to prove that the plate is a modified brachial. We think the evidence derived from them shows conclusively that it is an interradial plate. If the ventral sac represented a modified arm, we should like to know to which ray the plate in *Heterocrinus* and *Ectenocrinus* belongs, whether to the right or to the left? In *Dendrocrinus casei*, in which the case is somewhat complicated, we would have three modified arms, one to the right, one to the left, and one supported by the plate X. *Dendrocrinus caduceus* (Pl. X, fig. 11) would have variously two or three such arms, two resting upon the upper sloping faces of adjoining radials, and both supported by the plate X. Still more inconceivable would be the case of *Hybocrinus* in which the so-called "brachianal" supports numerous small, irregularly arranged pieces forming a short protuberance.

In alluding to the anal structure of the Camerata, it has been pointed out that in the Actinocrinidae the first anal plate rests between the radials, contrary to the Melocrinidae, in which the lowest anal plate rests within the second row of interradial plates, and all

the radials are in lateral contact. The anal plate of *Actinocrinus* thus occupies a position toward the radials similar to that of the plate X in *Cyathocrinus*, and the anal plate of *Melocrinus* to that of the plate t (X of Bather) in *Hybocrinus*. We have not the least doubt that the plates of the two former genera are homologous with one another, and also those of the two latter among themselves, but we go no further. We believe that in *Melocrinus* and *Hybocrinus* the plate X is unrepresented, and the structural changes that took place afterwards in *Actinocrinus* and *Cyathocrinus* were not effected by a sinking of the tube, but by the introduction of an additional plate.

We now return to *Dendrocrinus*, and take up those forms in which the lower section of the posterior radial turns into a supplementary anal piece. The first step in this direction is shown by *Homocrinus*, *Botryocrinus*, *Oncocrinus* and *Barycrinus*, in all of which the upper or arm-bearing portion of the radial has shifted slightly to the right, and is connected with the lower by an oblique suture. Here the plate X is comparatively large, occupying the whole space between the two posterior radials, and as no part of the ventral tube, as yet, is introduced into the dorsal cup, the plate R′ is physiologically and morphologically a radial, and not an anal plate.

Bather explains the evolution that took place in these forms by "the shifting of the radianal," and that "X has sunk still lower into the dorsal cup and is now on a line with the radials," in which we cannot agree with him. We have already pointed out that the radianal throughout this group retains the same position which it held when constituting a part of the radial. It always rests with its lower angle between the two basals, and only changes its outlines so as to conform to the adjacent plates. The widening of the anal area was effected by the shifting of the radials, which in *Dendrocrinus* and *Homocrinus* opened out for the insertion of the plate X, and by the increase in width which took place in the posterior basal simultaneously. There was no shifting of the radianal, nor any sinking of the plate X, but the latter retained the position which it held in *Dendrocrinus*.

In *Parisocrinus*, *Atelestocrinus*, *Euspirocrinus*, and in most of the Poteriocrinidae, the width of the anal area is increased again. In these genera, the arm-bearing section of the right posterior radial moved away from the lower section so as to be placed almost directly upon the right postero-lateral basal, and a new plate was in-

troduced between the radial and the plate X, supported by the radianal—the former R′.

The derivation of the Poteriocrinidae, etc. was explained by Bather as follows: "in the Poteriocrinites another change has taken place; the radianal has passed through a revolution of 90°, and the lowest plate of the ventral sac (t) has sunk down between R and X." We are somewhat in doubt what Mr. Bather means by "revolution of 90°," but suppose it refers to the change in the position of the radianal toward the right posterior radial. If he means that here the radial moved away from the radianal, we agree with him; but if it implies the radianal shifted away from beneath the radial, we cannot follow him, for that plate, as already stated, retains its position throughout the different phases of its development, and only undergoes modifications in size and form, until it disappears entirely. That the lower part of the tube "sunk down between R and X" appears to us doubtful. It is more probable that a new plate was introduced beneath the other, a sort of third anal, and this is partly confirmed by the fact that the plate is imperforate.

This explains the anal structure of all Poteriocrinidae except that of *Ulocrinus*, *Graphiocrinus*, *Ceriocrinus* and *Erisocrinus*, which we regard as transition forms toward *Enerinus*. The ventral tube, which through these forms dwindles down again to a short cone, no longer necessitated the same representation in the dorsal cup, and as the anal plates gradually diappeared, the posterior radials assumed a symmetrical position. In the new genus *Ulocrinus* of S. A. Miller the plate X ceased to be represented, and its place was taken by the radianal; while in *Graphiocrinus* and *Ceriocrinus* only the plate X is represented. In *Graphiocrinus*, in which the ventral tube is quite capacious, the plate X is comparatively large; while in *Ceriocrinus*, with a small tube, it is reduced to a very narrow piece, which rests upon the greatly extended posterior basal. In *Erisocrinus*, *Stemmatocrinus* and *Encrinus* the latter plate also disappeared, and the tube came to rest upon the edges of the radials, where it started in *Hybocrinus*, *Ectenocrinus* and allied forms.

From the above considerations it appears to us that Bather's theory respecting the "brachianal" is based upon a misinterpretation of the plates. If it were true that the plate resting to the left of the radial of *Iocrinus*, passed in later forms down to the basals, it would mean nothing less than a partial revolution of the entire tube to the left. Consulting the specimens it will be found that in this genus

and in the Fistulata generally, the plate alluded to is succeeded by a vertical row of plates in the tube, and that the anal plate (X), where it exists, is followed by another row of plates, arranged in the same way, and placed aside of the first row. Moreover, how can that plate on the separation of the radials sink to the bottom of the dorsal cup, when the anterior side of the tube rests upon the ventral disk? It would be practically impossible unless this side was lowered also. Is not the evolution that here took place more reasonably explained if we assume that on the separation of the radials the space between them was filled by an additional plate?

We hold that the Fistulata have but one true anal plate—the plate X—and that the radianal is a sort of supplementary radial, which in some genera performed the functions of an anal plate. The anal plate of the Camerata, when present, as before stated, invariably occupies the middle line of the posterior area, so as to separate the interbrachial plates into two equal divisions, even splitting the plates in rows in which there is an uneven number. Under such circumstances it seems unreasonable to assume that the plate X is a brachial, and the anal tube a modified arm. This suggestion was made at first by us, but given up in 1883, finding it not sustained by the phylogeny of the group. If it was a modified arm, the arm structure should be indicated in *Hybocrinus*, one of the *earliest* known Crinoids; but, unfortunately for Bather's theory, the ventral sac in this genus consists of only a small protuberance, composed of irregularly arranged pieces. Nor do we find anything among Cystids to support this hypothesis, and certainly not among Blastoids. The theory is based wholly on a superficial resemblance between the tube and arm-plates in *Iocrinus*, and a misconception of the right posterior radial which Bather took to be an axillary plate. But even this apparent resemblance fades away on examining the tube with the arms removed and the outer wings of the tube visible.

Bather made no comparison with the anal plates of the Camerata. He obviously regarded them as morphologically distinct from those of the Fistulata, for on p. 319 he says: "it may be pointed out that, as interradials do not enter into the composition of the dorsal cup in any Fistulata, none of these plates can well be homologues of interradials: in many of the Camerata actual interradials are present in the anal area, but in the Fistulata at least we must look else-

where for the origin of the so-called 'anal' plates." To this we reply, there are "interradial plates" in the Fistulata as well as in the Camerata, but they are in the former interambulacral and not interbrachial, owing to the fact that the arms are free from the radials. All plates between the rays, those between the ambulacra, and all the plates of the ventral sac, those supporting it, and the plates of the anal tube, are parts of the same element.

The symmetry of the Crinoids, as a rule, is bilateral, and the anal area occupies the median axis. The asymmetry, which occurs in so many Fistulata and certain Ichthyocrinidae, is caused by irregularities in the radials. Wherever these have attained a regular form, the plate X takes its median position, and the plates of the ventral tube also are arranged on a strictly bilateral plan. Whether the symmetrical form, as represented in the Silurian Cyathocrinidae, was evolved from the asymmetrical form, we are unable to ascertain. It is possible that the two had a common symmetrical ancestor, but it seems to us more probable that all were at first asymmetrical, and that the lower section of the posterior radial became early resorbed in some cases. Against the former theory it may be said that in the Lower Silurian Fistulata, so far as known without exception, the right posterior radial is compound, and that we find the symmetrical form along with the other in the same families; against the latter, that the symmetrical form is already well represented in the Upper Silurian.

We have made no reference to the Calceocrinidae, as we have not at present the material to study the older forms, but we are quite certain that their structure is in conformity with that of the other Fistulata. The statement, that "*Castrocrinus* shows a series of anal plates supported by the first costal of the left posterior radius, which is exactly comparable to the arm-bearing costal of the right posterior radius," leads us to suspect that there is also here a misinterpretation of the plates.

In the Ichthyocrinidae the anal structure resembles that of the Fistulata. In some of them both anal plates are represented, in others only the plate X; while in the genus *Ichthyocrinus*, both plates are absent. The following table shows the distribution of the anal plates in the different genera, and the representation of interbrachial plates.

| | *Ichthyocrinus.* | *Taxocrinus.* | *Forbesiocrinus.* | *Calpiocrinus.* | *Mespilocrinus.* | *Sagenocrinus.* | *Pycnosaccus.* | *Gnorimocrinus.* | *Lecanocrinus.* |
|---|---|---|---|---|---|---|---|---|---|
| Plate X represented. | ... | X | X | X | X | X | X | X | X |
| Radianal represented. | ... | ... | ... | ... | ... | X | X | X | X |
| Interbrachials present at all five sides. | ... | X | X | X | ... | X | ... | X | ... |

In *Taxocrinus* and *Onychocrinus*, the plate X is followed by a vertical row of additional pieces forming a lateral tube; in *Calpiocrinus* by one or two large plates longitudinally arranged, resting between the radials; in *Forbesiocrinus* by a great number of large interbrachial plates; in *Mespilocrinus* by one plate only. The anal area of *Sagenocrinus* is similar to that of *Forbesiocrinus*, that of *Lecanocrinus* and *Pycnosaccus* like that of *Mespilocrinus*, the presence of the radianal excepted; and *Gnorimocrinus* in its anal structure resembles closely *Taxocrinus*, but the tube of the former rests obliquely, and not vertically, upon the plate X, and partly upon the radianal.

There has been considerable doubt as to the row of plates in the anal interradius of *Onychocrinus* and *Taxocrinus*, whether they are incorporated into the calyx, as the anal plates of *Reteocrinus*, or form a free tube. We can now state from actual observation that the latter is the case, at least in some species. At the special request of Dr. Carpenter, we dissected some fine specimens, and in *Onychocrinus exculptus*, *O. ulrichi*, and in a large species of *Taxocrinus*, succeeded in laying bare the tube at all sides. The posterior side consists of a vertical series of eight or nine large subquadrangular plates, loosely connected, and sometimes separated by very minute pieces. The anterior side is composed of a large number of quite small perisomic plates, forming a sort of pouch, wider at the proximal end. In all of those species, the tube at its anterior side leans considerably to the right, and we suggest from this structure that both genera were derived from the asymmetrical *Gnorimocrinus*, which occurs in the Upper Silurian contemporaneously. The tube at its distal end

is rounded, composed of irregular pieces, pierced by a small aperture, which opens out somewhat anteriorly and evidently served as anus. The structure indicates clearly, that this tube is quite different from the solid conical protuberance which occurs in the recent genus. *Thaumatocrinus*, with which it has been compared. The latter we regard as a most remarkable instance of atavism. The projection consists of a vertical row of fourteen or more plates rising to the height of the anal tube, placed in front of it. It recalls the ventral sac of the Fistulata, among which also apparently the anus sometimes is placed in front of the tube. In *Coeliocrinus* with a balloon-shaped sac, which is sometimes found detached so it can be examined from all sides, we have searched in vain for an opening, and we have no doubt that in this genus, and probably in many others, the anus was located near the mouth as in *Thaumatocrinus*.

No other genus among the Crinoids has so wide a range, and undergoes so few modifications as *Ichthyocrinus*. We find it already in the Lower Silurian, and it lived through to the time of the Upper Coal Measures, and was quite probably the ancestor of the Apiocrinidae, Pentacrinidae and Comatulidae of our present seas.

There are in the paper of Mr. Bather several inaccurate references to our previous writings, to some of which we are compelled to direct attention, as much as we regret it, else it would appear that we had actually made such inconsistent and irrational statements.

On p. 322, he says that in our paper on *Hybocrinus*, *Hoplocrinus* and *Baerocrinus*, we considered the "Azygos plate to be an independent morphological element of the dorsal cup, *not* a modified radial," and on p. 323, he alludes to our "previous view that the Azygos plate was a primitive fundamental element of the dorsal cup." We know of no passage in that paper from which Bather would be entitled to draw any such inferences. As he lays so much stress upon this in his criticism, he should have quoted the exact language, and give the page where it occurs.

On p. 324, in summing up the position which we held in 1886, he makes the following astonishing statement:

"(1.) Azygos plate (Az) a primitive element of the dorsal cup.

(2.) Anal (x) and right posterior radial derived from Azygos plate.

(3.) Anal of *Antedon* not homologous with any plate of the Fistulata, but an embryonic interradial."

A careful examination of both sections of Pt. III of the Revision, will show nothing to justify Bather in assuming that we regarded the Azygos as a "primitive element." We only stated on p. 11: "the lower segments (of the compound radials) are probably embryonic plates, which were resorbed by the upper segments." We admit that the expression "resorbed by" was badly chosen, we should have stated: were resorbed *and occupied* by the upper segments, but that is not the issue here.

Bather's second statement is equally inaccurate. If he had said that we regarded the anal plate (X) and right posterior radial as derived from the *undivided Azygos in Baerocrinus*, he would have expressed our views.

His third statement is more faulty yet. To agree with Pt. III of the Revision it should be amended as follows: Anal plate of *Antedon* larva *homologous* with plate X of the Fistulata, and interradial in position. At that time we thought it even possible, and said so on pp. 39 and 40, that the anal plate of *Antedon* was developed from an "Azygos plate," and that: "Possibly the undivided Azygos plate, *as represented in Baerocrinus*, has been overlooked in the larva." We stated further on the same page "that at least in *Cyathocrinus* the latter (Azygos) plate was entirely removed, and the anal plate took the position of that in the larva of *Antedon*," thus showing conclusively that we regarded the two plates as structurally identical.

Another incorrect statement we find on p. 323. There Bather asserts that we stated "the 'anal' of *Antedon* larva is an interradial with special function, while the Azygos plate is as much radial as interradial." The fact is we said the Azygos plate "*in Baerocrinus*," and not the Azygos generally, is as much radial as interradial. In a supplementary note to his paper, in the June number of the Annals, on p. 486, he alludes to this omission, stating that he left out the words purposely, "since they (we) in the very next sentence imply that *Baerocrinus* is an ancestral stage," and "that a simple and exact quotation would have tended to confuse the issues." This is taking altogether too great liberty with the text. We stated correctly that the "Azygos of *Baerocrinus* is neither radial nor interradial," for it rests between two radials and alternates with the basals; but to say the same thing of *Homocrinus*, *Dendrocrinus*, etc. would be ridiculous.

## PLATE IX.

Fig. 1. VENTRAL DISK OF CYATHOCRINUS ALUTACEUS Angl.
The orals in lateral contact, and covering nearly the whole ventral surface. Refigured from the type specimen in the Zoöl. Riks Muset at Stockholm (Iconogr. Crin. Suec. Pl. XXIII, fig. 11).

Figs. 2 and 3. VENTRAL DISK OF CYATHOCRINUS LAEVIS Angl.
Fig. 2, specimen in which the orals are partly resorbed.
Fig. 3, another specimen, in which the orals are replaced by large covering pieces.
From the same Museum (Iconogr. Pl. XXVI figs. 2 and 3b).

Figs. 4 and 5. VENTRAL DISK OF EUSPIROCRINUS SPIRALIS Angl.
The orals replaced by large ambulacral plates uniting in the center.
(Same Museum, Iconogr., Pl. IV, figs. 7d and 7e).

Fig. 6. VENTRAL ASPECT OF A SPECIMEN OF CYATHOCRINUS GILESI W. and Sp.
The "consolidating plates" in part covered by small perisomic pieces; the ambulacra not preserved.
(Collection of Wachsmuth and Springer).

Fig 7. VENTRAL DISK OF CYATHOCRINUS BREVISACCULUS W. and Sp. (n. spec.).
Showing the "madreporite." The oral center closed by the fused covering and side pieces; the "consolidating plates" partly exposed.
(Same collection).

Fig. 8. VENTRAL DISK OF CYATHOCRINUS NODOSUS W. and Sp. (n. spec.).
Showing the "madreporite," the ambulacral and interambulacral plates.
(Same collection).

Fig. 9. VENTRAL ASPECT OF A VERY YOUNG SPECIMEN OF CYATHOCRINUS BREVISACCULUS.
The orals partly intact.
(Same collection).

Fig. 10. VENTRAL ASPECT OF THE TYPE OF MARSUPIOCRINUS DEPRESSUS Angl.
Specimen in the Zoöl. Riks Muset at Stockholm (Iconograph. Pl. X, fig. 16).

Fig. 11. INNER FLOOR OF THE TEGMEN IN PHYSETOCRINUS.
Showing the cavernous pits and passages. The braces represent the thickened interradial portions, which form the galleries for the reception of the ambulacral skeleton.
(Collection of Wachsmuth and Springer.)

Fig. 12. POSTERIOR OR ANAL SIDE OF DENDROCRINUS CASEI Meek.
From a specimen in the collection of Wachsmuth and Springer.

(All figures are enlarged two diameters, except fig. 9 which is enlarged four times, and fig. 11 which is but one-half larger).

PLATE X.

Fig. 1. VENTRAL DISK OF CYATHOCRINUS HARRODI W. and Sp.
Showing the structure of the ambulacra, and the ventral sac to its full length.
(Collection of Wachsmuth and Springer).

Figs. 2 and 3. CYATHOCRINUS IOWENSIS O. and Shum.
Fig. 2. Specimen in which only the "consolidating plates" are *in situ*.
Fig. 3. Another specimen, in which the "consolidating plates" are covered over by ambulacral and interambulacral plates; the orals are partly resorbed.
(Same collection).

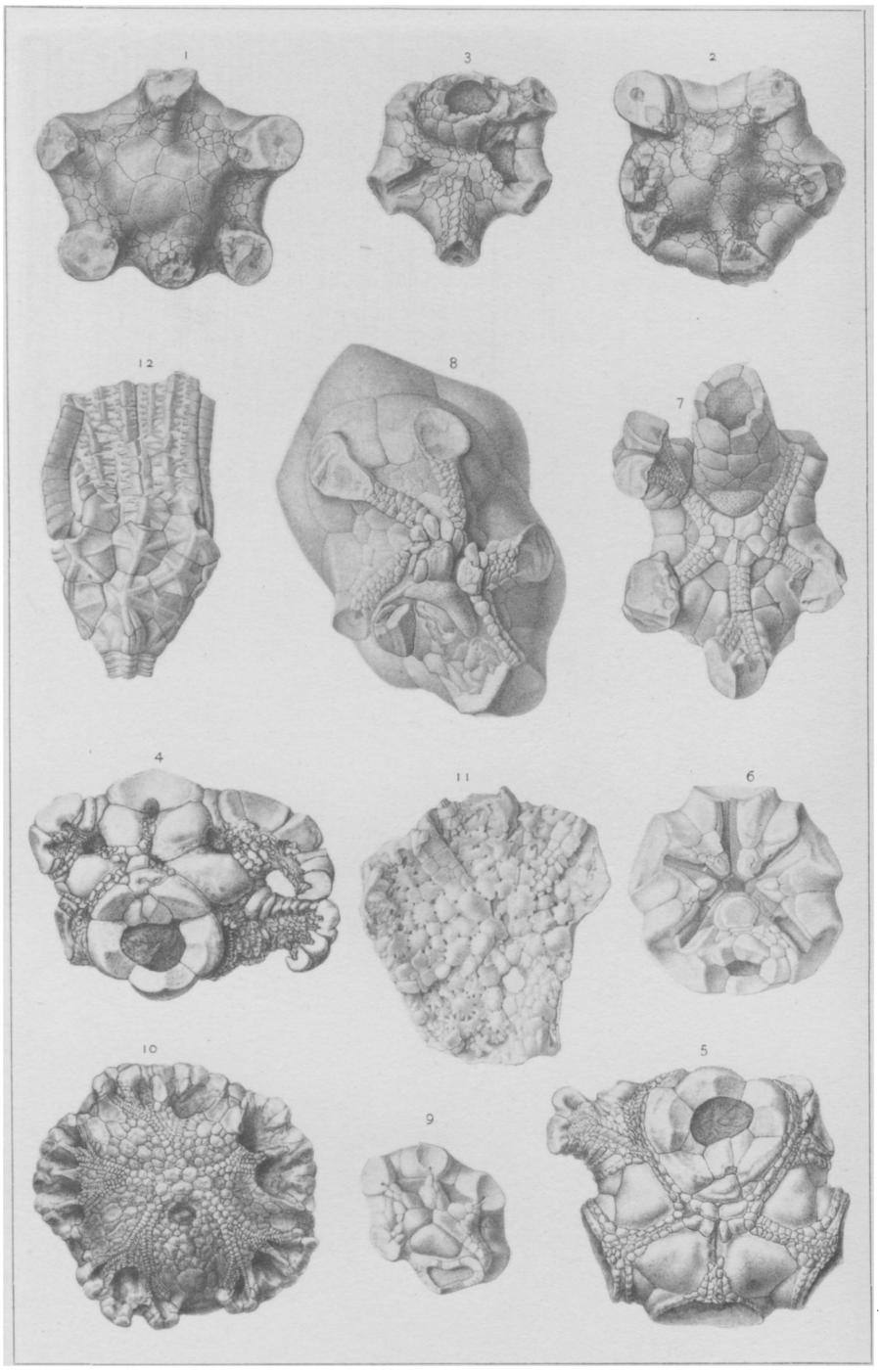
Fig. 4. CYATHOCRINUS LONGIMANUS Angl.
Showing the arrangement of plates in the tube. (After Angl.).

Figs. 5a, b. IOCRINUS SUB-CRASSUS Meek and Worthen.
a, posterior aspect; b, portion of the ventral tube enlarged.

Figs. 6 to 14. DIAGRAMS SHOWING THE RELATIONS OF THE ANAL PLATES TO SURROUNDING PARTS.
Fig. 6, in *Baerocrinus*; fig. 7, *Hybocrinus*; fig. 8, *Heterocrinus bellevillensis*; fig. 9, *Ectenocrinus simplex*; fig. 10, *Anomalocrinus*; fig. 11, *Dendrocrinus caduceus*; fig. 12, *Poteriocrinus*; fig. 13, *Ceriocrinus*; fig. 14, *Ulocrinus*.

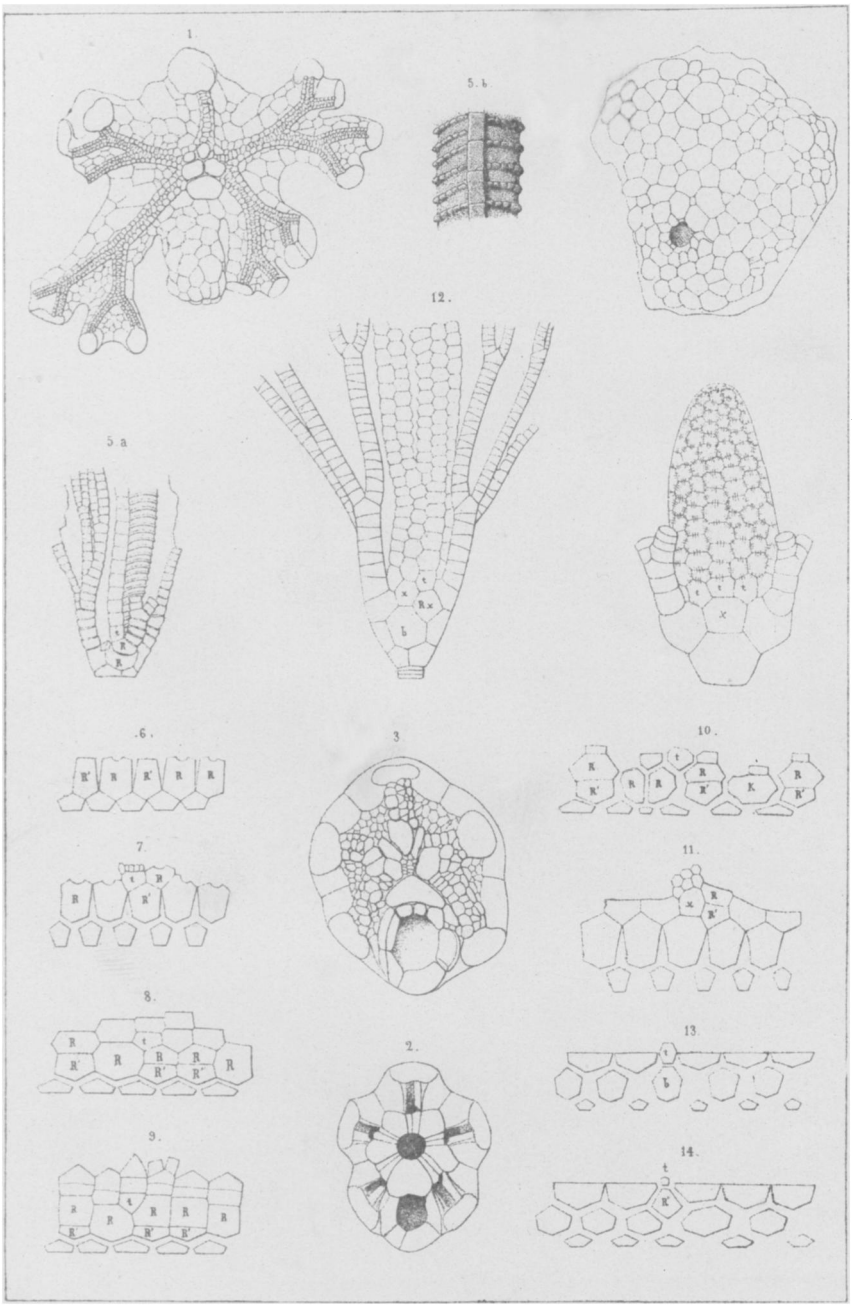
EXPLANATION OF LETTERING.

R. Radial.
R′. Lower half of a compound Radial.
$R^x$. The latter assuming anal functions=Radianal.
X. The true anal plate.
t. Plates of the ventral tube.




G. Liljvall, A. M. Westergren, del.

WACHSMUTH AND SPRINGER ON PERISOMIC PLATES.

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Wachsmuth and Springer on Perisomic Plates.